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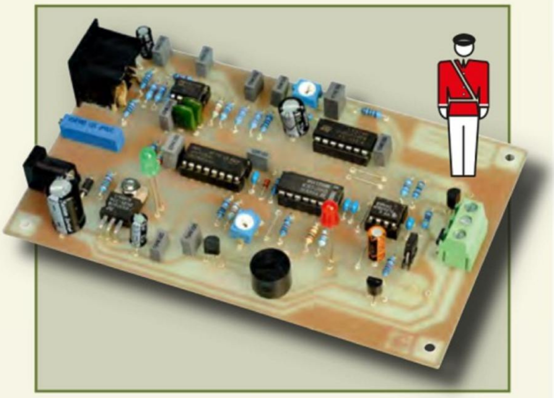
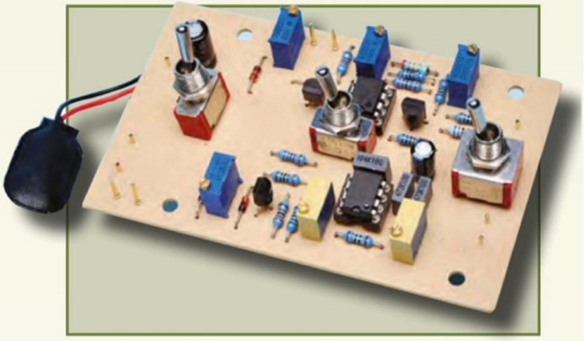
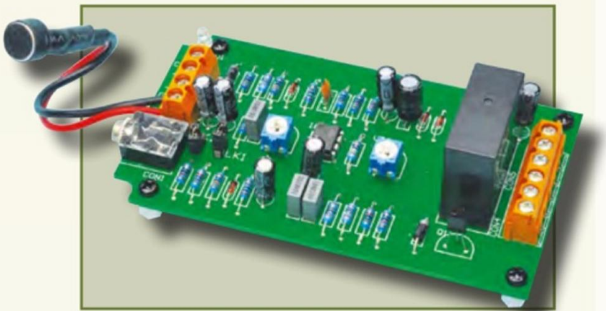
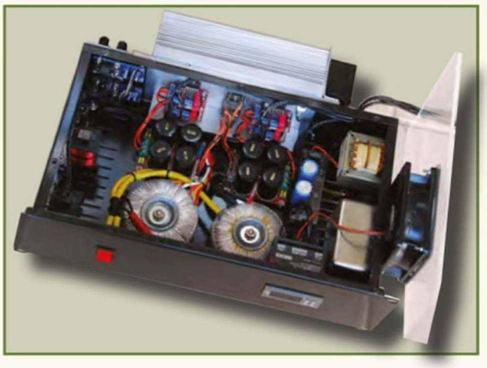








Our September 2013 issue will be published on Thursday 1 August 2013, see page 72 for details.

Projects and Circuits

Series and Features

Regulars and Services

Driveway Sentry

Here's a Driveway Sentry. It detects vehicles like cars, trucks, tractors or other farm machinery moving along a driveway or through a gateway. When movement is detected, it switches on a mains-powered or battery-powered lighting system and activates an optional piezo buzzer alarm for a preset period ranging from 2-25 seconds.

The *Driveway Sentry* circuit is housed in a plastic jiffy box and switches on lights when a vehicle drives over a driveway detector loop.

By Jim Rowe

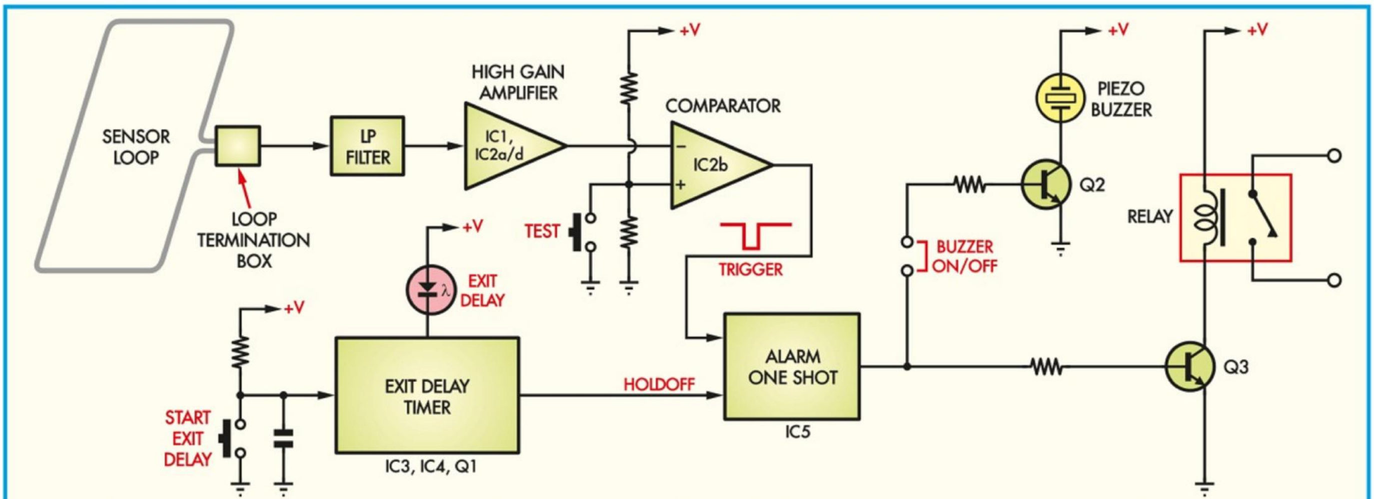


Fig.1: block diagram of the *Driveway Sentry*. The sensor loop detects a vehicle passing over it and the resulting signal is filtered, amplified and fed to comparator stage IC2b. This then triggers a monostable, which turns on transistors Q2 and Q3 to drive a buzzer and activate a relay to switch on the lights.

UNLIKE OTHER motion-sensing systems that use light, heat or ultrasonic sound waves to detect motion, the *Driveway Sentry* operates by sensing small changes in the Earth's magnetic field – the same magnetic field that's sensed by a compass.

Since cars, trucks and similar vehicles contain a significant amount of ferrous metal (iron, steel), they inevitably produce small temporary changes in the Earth's magnetic field when they move into or through an area. Detecting that phenomenon is how the *Driveway Sentry* operates. Despite its sophisticated sensing technique, this project simply uses a loop of sensing cable buried under the driveway to detect passing vehicles.

No interference

Because it doesn't generate any sensing fields of its own, the *Driveway Sentry* produces no electromagnetic interference; it's quite 'clean'. Also, because it only senses moving iron and steel objects like vehicles, it's much more selective than other kinds of sensor. This makes it virtually immune to false alarms from birds, dogs, cats, sheep, foxes and other animals, falling tree branches, rain and snow, people walking past (unless they're Iron Man!) and so on.

At the same time, it can be used to detect the movement of vehicles which contain very little steel – like aluminium trailers, boats and caravans – simply by attaching a strong magnet to the underside of their chassis. The magnet ensures that if they're moved past the *Driveway Sentry's* remote sensor loop, the Earth's magnetic field will be disturbed locally and the system will activate.

In short, the *Driveway Sentry* has a multitude of motion-sensing uses around the home or farm. It operates from 12V DC and draws very little current – less than 15mA when armed and waiting, and no more than 100mA when it senses movement and is 'alarmed' or activated. Thus it can be operated from a 12V battery and/or solar power as an alternative to a DC plugpack supply.

Main features

The *Driveway Sentry* detects moving vehicles by sensing the small temporary changes in the Earth's magnetic field caused by this motion. It detects the changes using a rectangular sensor loop which is buried under the driveway, or concealed with two opposite ends of the loop in the expansion gaps in the driveway itself.

Exit Delay: allows the system to be switched to non-sensing 'sleep mode' for a period of about five minutes, to allow the owner's vehicle to exit from the property without activating the *Driveway Sentry*. At the end of the Exit Delay, the system returns to its movement sensing mode.

Test Button: allows the system to be manually triggered into 'movement detected' alarm mode without having to drive a vehicle over the remote sensing loop. This makes system adjustment easier and more convenient.

Piezo Buzzer: produces a high-pitched sound to attract your attention when movement is detected. This sound can be disabled if you prefer the system to respond silently.

Relay Contacts: includes an SPST relay with mains-rated contacts. The relay is activated when the system detects movement, allowing the unit to be connected to control mains lighting or other equipment such as a high-powered siren.

Alarm Duration Control: allows the duration of the system's 'movement detected' alarm mode to be adjusted between a minimum of two seconds and a maximum of about 25 seconds.

Sensitivity Adjustment: allows the sensitivity of the *Driveway Sentry* to be adjusted over a wide range, so it can be set for reliable vehicle detection without being too sensitive and susceptible to false alarms.

Low Power Consumption: unit operates from 12V DC power (normally a plugpack), with a low current drain: <25mA in Exit Delay mode (<300mW), <15mA in armed mode (<180mW) and <100mA in alarm (movement detected) mode (<1.2W). This means that the system can also be operated from a 12V SLA battery and/or solar power in rural and other remote situations.

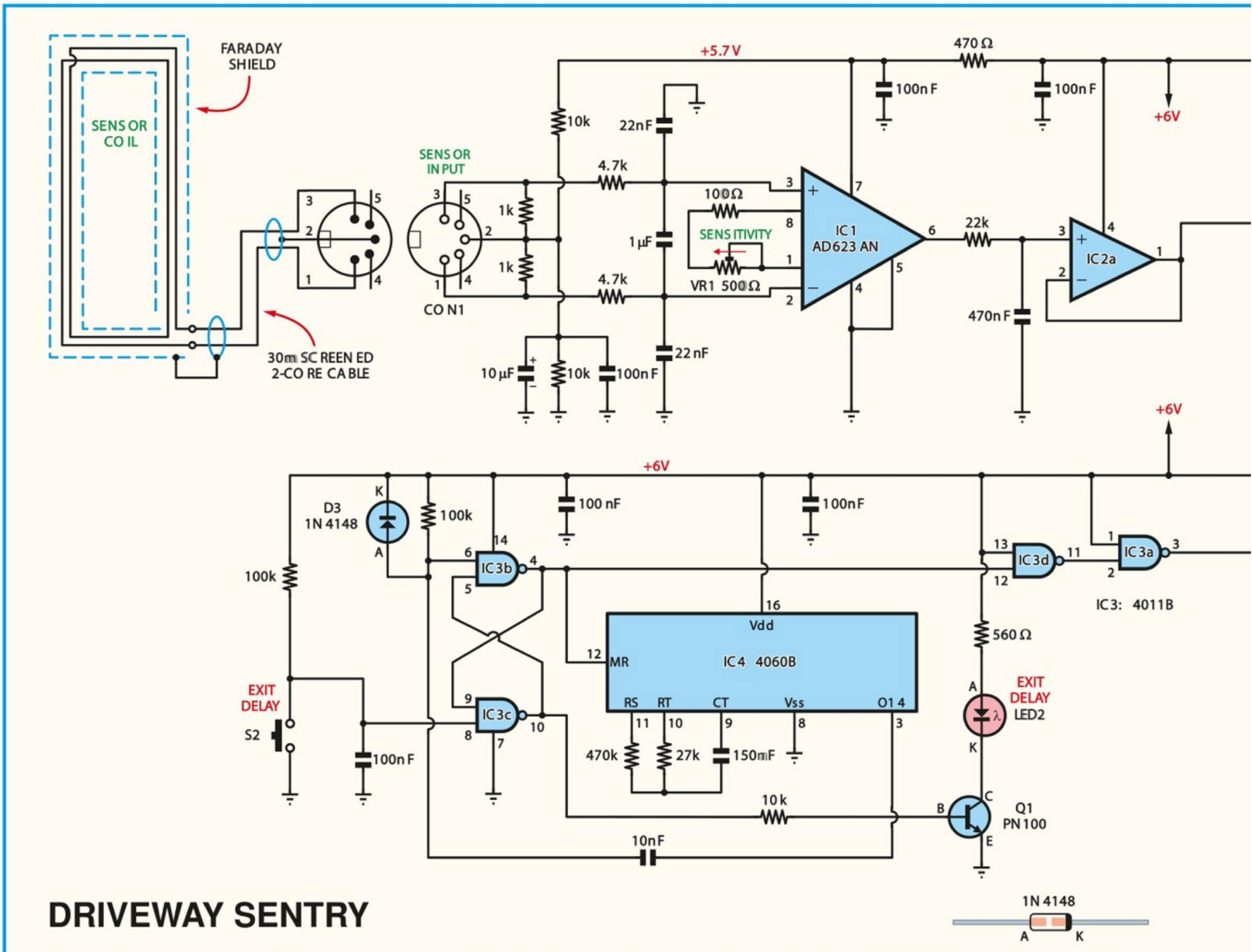


Fig.2: the circuit uses five low-cost ICs. IC1 (AD623AN) provides most of the signal gain for the loop sensor signals, while 7555 timer IC5 forms the monostable. Counter stage IC4 and its associated circuitry provide an exit delay.

How it works

The heart of the *Driveway Sentry* is a rectangular loop of shielded multi-conductor cable. This can either be concealed in the expansion joints of a driveway or laid under the driveway or gateway to be monitored. The ends of the loop are fed into a small waterproof box, where the starts and finishes of the various conductors are terminated to form a multi-turn loop.

When tiny, low-frequency AC voltages are induced in the loop turns as a result of magnetic field disturbances, they are fed back to the *Driveway Sentry's* main box via a twin-shielded cable, amplified and used to trigger the alarm circuit.

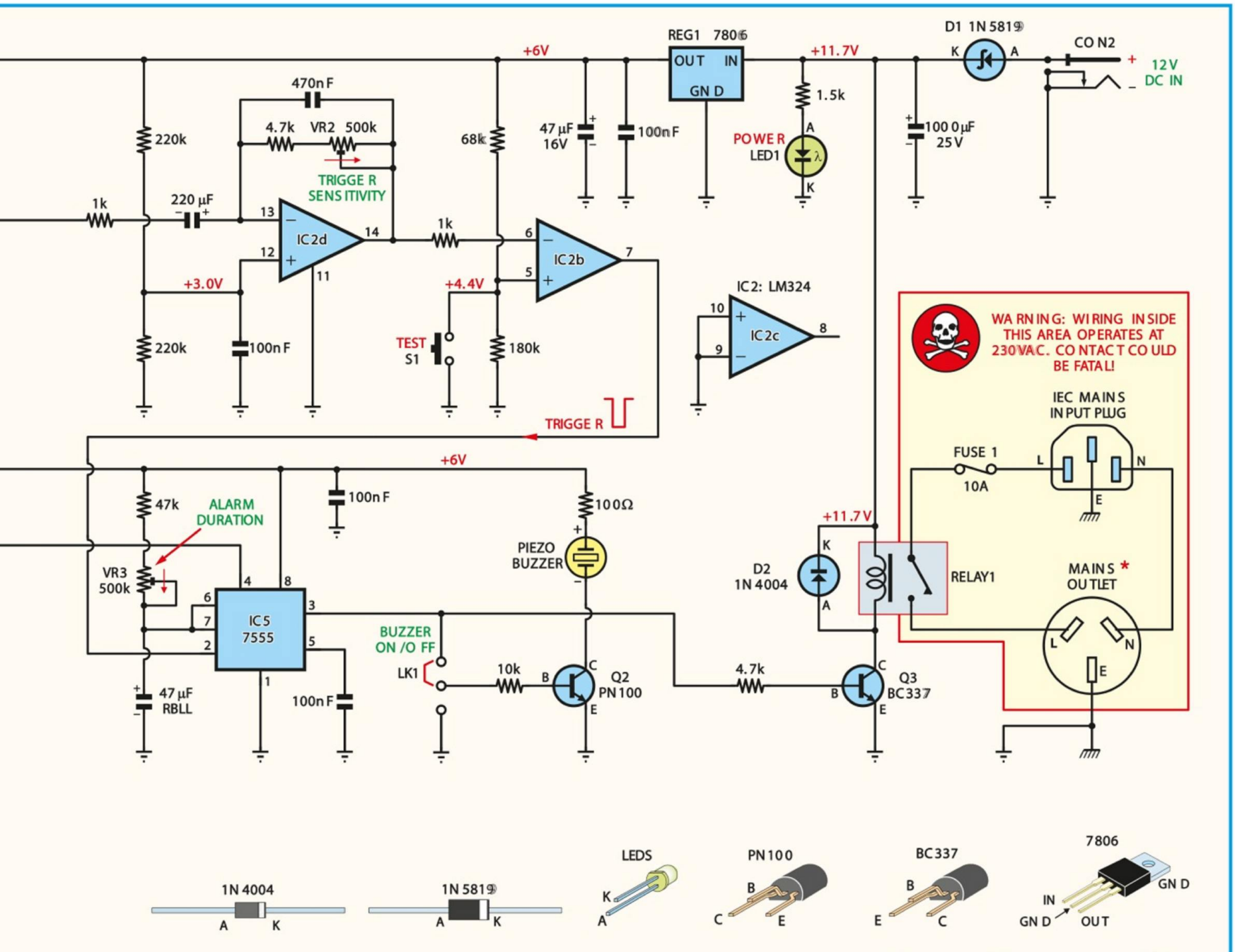
Because the sensor loop also tends to pick up a significant amount of electrical noise, it needs to have a Faraday shield. This job is done by the screening layer of the loop cable which is connected (at one end only) to the shield braid of the output cable. This provides an electrostatic shield without also forming a shorted turn.

Fig.1 shows how it works. The tiny voltages induced in the loop are first passed through a fairly drastic low-pass filter to attenuate all noise, hum and spurious signals above about 13Hz. This is possible because the signals we want to detect are of a very low frequency – only a few Hertz. The filtered signals are then fed to a high-gain amplifier (IC1, IC2a and IC2d), where they are amplified by up to 500,000 times. They are also further filtered, giving an overall attenuation of about 40dB for any spurious signals at 50Hz and above that may be picked up.

The amplified signal is then biased to a DC level of 3V and fed to one input of a comparator (IC2b). Here it is compared with a reference DC voltage of 4.4V at the second comparator input. When the peak value of the amplified sensing loop signal exceeds this reference level, the output of the comparator switches low.

The resulting negative-going pulse is then used to trigger IC5, a monostable pulse generator (or one-shot). When this happens, the output of the one-shot switches high, turning on transistor Q3 and energising the relay.

The relay contacts can be used to switch power to a siren, turn on security lights or trigger a security system. At the same time, the high level at the



* see note on page 20

output of the one-shot can be used to turn on transistor Q2, which activates a small piezo buzzer mounted in the *Driveway Sentry's* control box. However, if you don't want this internal buzzer to sound, it can be disabled.

The TEST pushbutton switch can be used to temporarily ground the positive input of comparator IC2b. This forces the comparator's output low, triggering the one-shot in the same way as a signal peak from the high-gain amplifier. So the TEST button allows you to do things like adjust the alarm duration without having to drive a vehicle over the cable loop.

As shown in Fig.1, the rest of the circuitry is used to provide the *Driveway Sentry's* 'Exit Delay' function. This operates by holding off the one-shot for a fixed period of about two minutes after power is first applied to the *Driveway Sentry*, or after the 'START EXIT DELAY' pushbutton is pressed at any later time. With the one-shot prevented from triggering during that time, you are able to leave in your own vehicle before the *Driveway Sentry* is re-armed.

Circuit description

Now let's have a look at the full circuit in Fig.2. The sensor loop is at upper left. For clarity, it's shown with only two turns, although with the recommended 9-conductor screened cable there will actually be nine turns.

The loop is connected to the input of the main circuit in the *Driveway Sentry* via a length of screened 2-core cable. This ends in a 5-pin DIN plug, which mates with input socket CON1, a 5-pin DIN socket.

The very weak signals from the sensor loop then pass through the main low-pass filter, formed by two 4.7kΩ resistors, two 22nF capacitors and a 1µF capacitor. They are then fed to the inputs of IC1, an AD623AN instrumentation amplifier, which provides most of the signal gain. The 100Ω resistor and 500Ω trimpot (VR1) connected between pins 1 and 8 of IC1 allow its gain to be varied between 168 and 1001, without significantly changing its common-mode rejection.

Note that the sensor loop's Faraday shield and the input cable's shield are not connected directly to earth but instead go to the half-supply bias voltage that's fed to both inputs of IC1. This bias voltage is derived from a voltage divider consisting of two 10kΩ resistors and is bypassed using 100nF

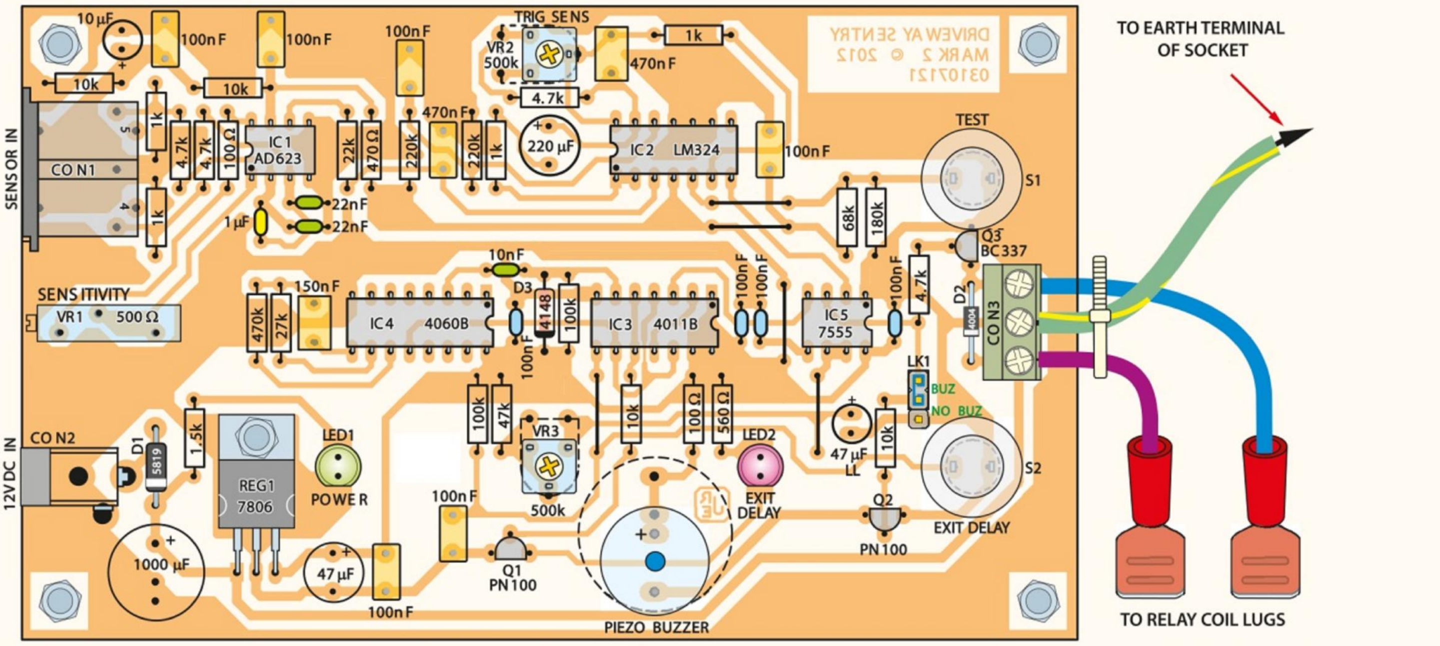


Fig.3: install the parts on the PCB as shown on this parts layout diagram. Take care to ensure that all polarised parts are correctly oriented, and be sure to make the leads to the relay coil lugs at least 80mm long.

and 10µF capacitors. It's then used to bias IC1's inputs via the 1kΩ resistors connected between pins 2 and 3 and 2 and 1 of CON1.

This means that there is virtually no DC voltage between the sensor loop conductors and their shielding, which improves the noise performance.

The amplified signals from IC1 emerge from pin 6 and then pass through another low-pass RC filter formed by a 22kΩ resistor and a 470nF capacitor. They then pass through IC2a, one section of an LM324 quad op amp that's used as a buffer to ensure that this RC filter is very lightly loaded. The buffered signals are then fed to the inverting input of IC2d via a 1kΩ resistor and a 220µF coupling capacitor.

IC2d provides the rest of the signal amplification, with its gain adjustable between 5 and 500 via trimpot VR2. It also acts as a low-pass filter due to the 470nF feedback capacitor. Its –3dB point varies with the gain setting so that only signals below 40Hz are amplified.

Note that IC2d only amplifies the AC component of the signals, with their mean value set to +3.0V by a voltage divider consisting of two 220kΩ resistors.

From there, the greatly amplified signal from pin 14 of IC2d is fed via a 1kΩ resistor to pin 6 of IC2b, configured as a comparator. Here it is compared with a +4.4V reference voltage at pin 5, as set by a 68kΩ/180kΩ voltage divider. When the signal applied to pin 6 of IC2b exceeds this +4.4V reference level, IC2b's output (pin 7) switches low, providing a trigger pulse for monostable IC5, a 7555 CMOS timer.

The trigger pulse from IC2b is fed to pin 2 of IC5, while pins 6 and 7 are tied together and connected to a timing circuit consisting of a 47kΩ resistor, trimpot VR3 and a 47µF low-leakage capacitor. VR3 allows the one-shot's 'alarm time' duration to be adjusted from about 2 to 25 seconds.

When IC5 is triggered (ie, pin 2 pulled low), its output at pin 3 switches high. This turns on Q3, which in turn activates Relay1 to switch power through to the mains outlet. At the same time, Q2 is turned on to activate the piezo buzzer, provided link LK1 is set to its upper position.

Exit delay

The exit delay circuit consists of a simple RS flipflop (IC3b and IC3c) plus IC4, a 4060B 14-stage binary divider with its own clock oscillator. When power is first applied or when S2 is pressed, the flipflop is switched into its reset state (pin 4 low) by the temporary low on pin 8. This low on pin 4 is applied to the reset pin (pin 12) of IC4, and as a result, IC4 starts counting.

At the same time, gates IC3d and IC3a (used here as inverters) apply a logic low to pin 4 of IC5, its reset input. This prevents IC5 from triggering in response to pulses from IC2b.

The timer's counting proceeds for a little over two minutes, after which IC4's O14 (pin 3) output finally goes low. This negative-going pulse is coupled via a 10nF capacitor back to pin 6 of IC3b, which switches the flipflop back into its set state.

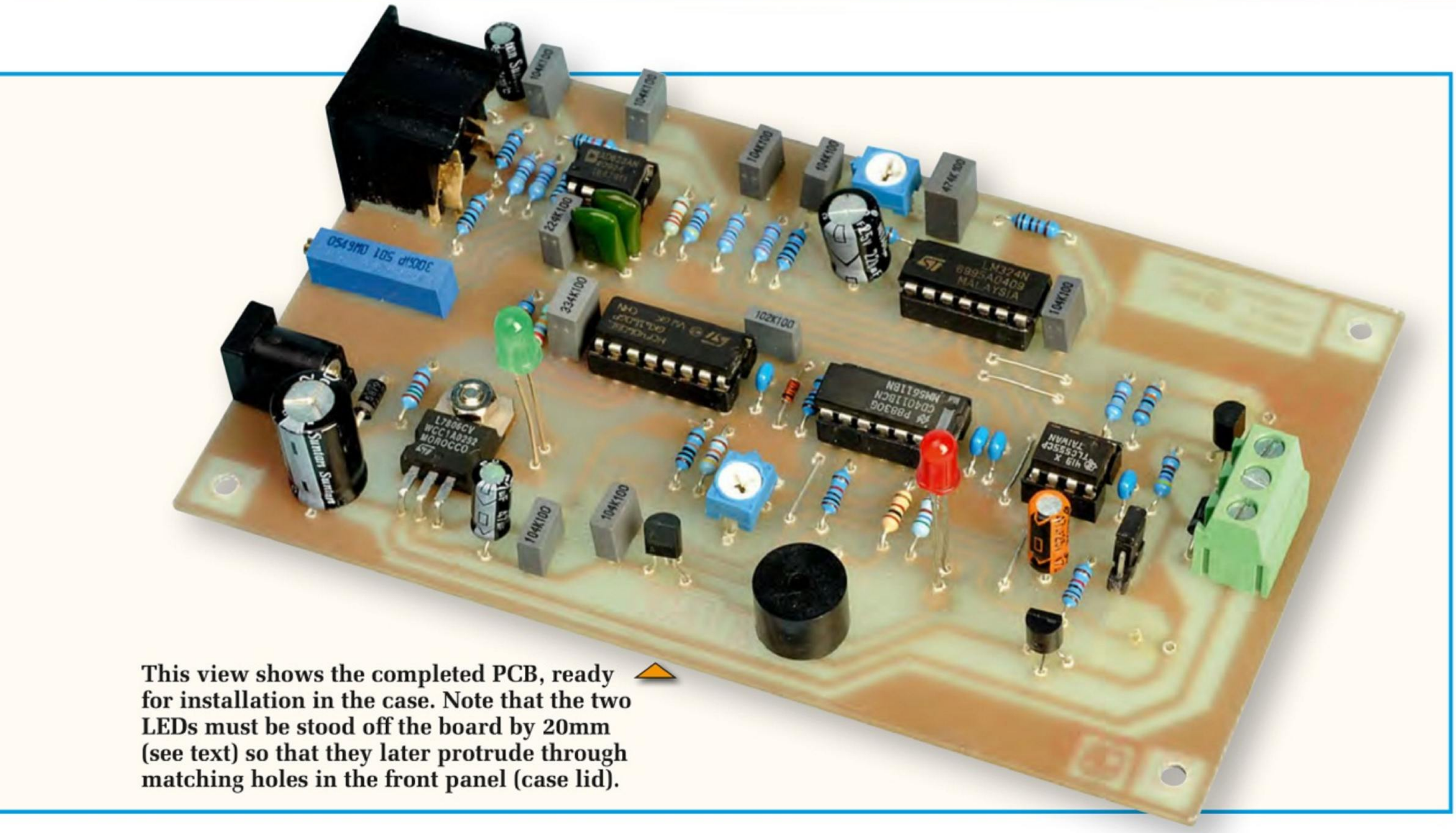
When this happens, pin 4 goes high and switches IC4 back into its reset state, thus stopping its oscillator and counter. At the same time, gates IC3d and IC3a apply a logic high to the reset pin of IC5, allowing it to be triggered again by any low-going pulses from IC2b. So the *Driveway Sentry* is armed (or re-armed) after a two-minute delay.

If you want a longer exit delay, simply replace the 150nF capacitor with a higher value (eg, 330nF for about five minutes).

During the exit delay time, there is a logic high on pin 10 of IC3c, the lower flipflop gate. This is used to turn on transistor Q1, which allows current to flow through LED2. This LED is therefore only illuminated during the exit delay period.

Power supply

The power supply section of the *Driveway Sentry* is very straightforward. Power comes from an external 12V DC plugpack, with Schottky diode D1 providing reverse polarity protection.



This view shows the completed PCB, ready for installation in the case. Note that the two LEDs must be stood off the board by 20mm (see text) so that they later protrude through matching holes in the front panel (case lid).

The output from D1 is decoupled using a 1000µF electrolytic capacitor and then fed to regulator REG1, which provides a stable +6V supply.

This +6V rail powers all of the circuit except for the relay, which is powered directly from the cathode of D1. Diode D2 across the relay coil protects Q3 from damage by quenching any back-EMF spikes that are generated when the relay turns off.

LED1 provides power-on indication, with the 1.5kΩ resistor limiting the current through the LED to about 7mA.

Construction

The assembly is straightforward, with most of the parts mounted on a PCB, coded 03107121, measuring 140mm × 84mm. This PCB is available from the *EPE PCB Service*. The only parts not on the board are the remote sensor loop, the output relay and the mains input and output connectors.

With the exception of the sensor loop, the parts are all housed in a standard UB2-jiffy box measuring 197mm × 113mm × 63mm. As stated, the remote sensor loop and its associated termination box connect to the main unit via a 2-core shielded cable.

Fig.3 shows the parts layout on the PCB. Begin the assembly by fitting the five wire links (or 0Ω resistors) to the board (note: if you have a double-sided PCB, these links aren't required). The resistors can then be installed, taking care to install the correct value at each location. You should also check each resistor using a DMM before installing it.

Follow with the non-polarised capacitors, then fit the polarised (electrolytic) capacitors. Ensure you fit the latter with the correct orientation, as shown on Fig.3. In particular, note that there are two different 47µF electrolytics. One is a low-leakage (RBLL) type and this goes in just below IC5. The other is a standard RB type, and this is installed just to the right of REG1.

Now fit the five IC sockets, taking care to orient their notched ends as shown on Fig.3. In particular, note that IC1 and IC2 face in the opposite direction to IC3, IC4 and IC5.

The diodes and transistors can now be installed. Be sure to orient these parts correctly, and take care not to get the transistors mixed up (Q3 is the BC337). Follow these with REG1, which is mounted horizontally at lower left. It's installed by first bending its leads down through 90° some 6mm from the device body. That done, it must be attached to the PCB using an M3 × 6mm machine screw, star lockwasher and nut before soldering its leads to their respective pads.

Next on the list are the three trimpots (VR1-VR3) and the piezo buzzer. Note that the PCB provides multiple mounting holes for the buzzer, to cope with different buzzer pin spacings.

Follow these parts with the 3-way SIL header strip for LK1, then install input socket CON1 and the 2.5mm DC power socket CON2. Make sure these parts are seated flush against the PCB before soldering their pins.

The two LEDs can now be installed. These must be oriented as shown (ie, with the longer anode lead to the top). They must also be stood off the board by 20mm. This can be done by pushing each LED down onto a 20mm-high cardboard spacer that's inserted between its leads before soldering the connections.

You can now complete the PCB assembly by plugging the five ICs into their sockets. Be sure to install the correct IC at each location and make sure they are correctly oriented (IC1 and IC2 face in the opposite direction to IC3-IC5). Note also that IC3, IC4 and IC5 are all CMOS types, so take the usual precautions to minimise the risk of electrostatic damage. If possible, earth yourself before picking them up and avoid touching their pins.

The *Driveway Sentry's* PCB assembly is now ready for testing.

Test and set-up

For the initial testing, there's no need to connect the remote sensor loop to the PCB assembly. However, you will need to temporarily connect a 27Ω

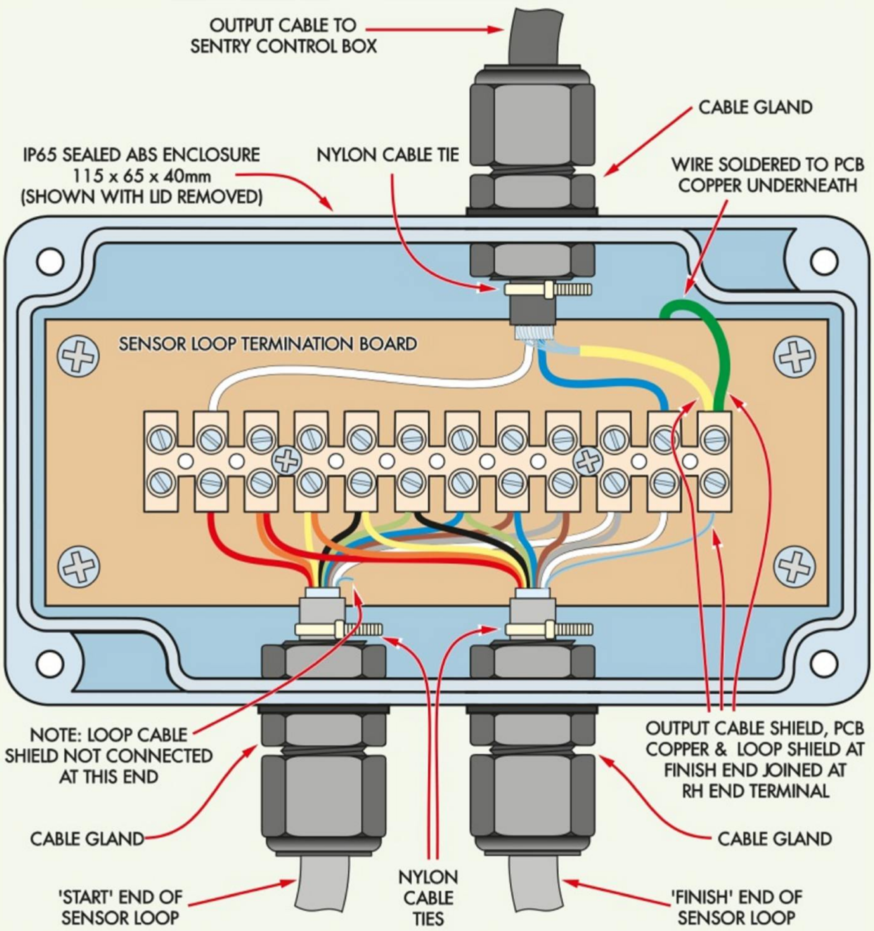
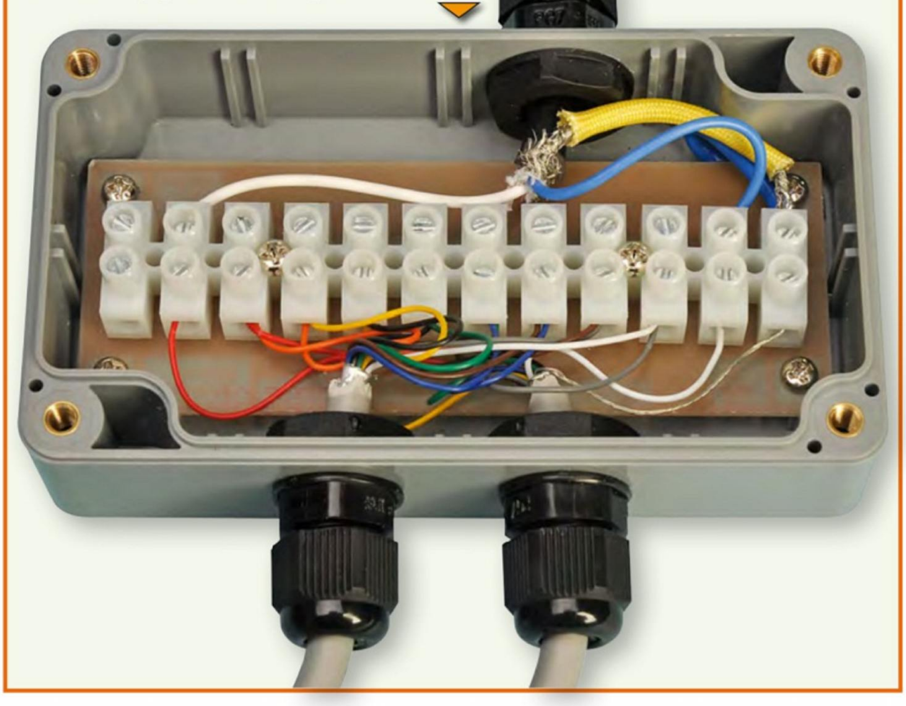


Fig.4: here's how to connect the wires from the sensor loop and the output cable inside the loop termination box. The 12-way terminal block is mounted on a 104mm × 38mm piece of blank PCB material. Note that an earth wire must be soldered to the copper on the underside of the PCB and connected to the earth screw terminal at far right.

Below: inside the loop termination box. Use cable glands and silicone to seal the cable-entry points, to keep moisture out.



resistor between pins 1 and 3 of CON1 as a passive 'stand in' (ie, between the two outer pins).

That done, connect a plugpack or another source of 12V DC to the DC input socket (CON2). If all is well, both LEDs should immediately light – LED1 to indicate that power is present and LED2 because the exit delay timing circuit has begun counting.

LED2 should now remain on for about two minutes after power-up. Similarly, it should also light and remain on for about two minutes after you press button S2.

Next, set trimpot VR3 to about midrange and check that link LK1 is in the 'buzzer' position. Now wait until LED2 goes out, showing that the exit delay circuit has timed out, then press TEST button S1. The piezo buzzer should immediately sound for about 10 seconds.

If the buzzer operating time is not to your liking (ie, it's too short or too long), this can be easily changed by adjusting trimpot VR3. The adjustment range is from about 2s up to about 25s.

The only other adjustment to be made to the *Driveway Sentry* is to vary the sensitivity of the sensor loop. This is done by adjusting trimpots VR1 and (if necessary) VR2 after the system has been installed and the remote sensor loop connected.

For the present, set VR1 fully anticlockwise and VR2 to midrange.

Making the sensor loop

As mentioned earlier, the sensor loop consists of a 25m-length of screened 9-conductor 'computer' cable, with the individual conductors connected in series to form multiple turns. The free ends of this multi-turn loop are then connected to a length of screened two-core extension cable, which connects to the main unit.

In addition, one end of the loop cable screen (ie, the braid) is connected to the screen of the extension cable, so that the Faraday shield can work correctly.

This is all achieved by bringing both ends of the loop cable and one end of the extension (or output) cable into a small IP65 enclosure, dubbed the 'loop termination box'. This enclosure measures 115mm × 65mm × 40mm and houses a small blank PCB fitted with a 12-way terminal block to facilitate the various connections.

Fig.4 shows assembly details for the loop termination box. As you can see, it's really very simple, with the

PCB supporting the 12-way terminal block for the necessary interconnections. The copper under the PCB is connected to the cable screens (at terminal 12), to provide a measure of screening inside the box.

All three cable ends are brought into the box via cable glands, with the two loop cable ends entering on one side and the output cable end entering on the opposite side. A nylon cable tie is fitted tightly around each cable just after it emerges from its gland, as an added precaution against the cable being pulled out accidentally.

Having stripped and secured the cables to the box, it's just a matter of wiring their leads to the screw terminal block, as shown in Fig.4. The wires at the 'start' end of the loop cable are connected in turn to screw terminals 2 to 10 on the PCB, while the 'finish' ends are connected to terminals 3 to 11.

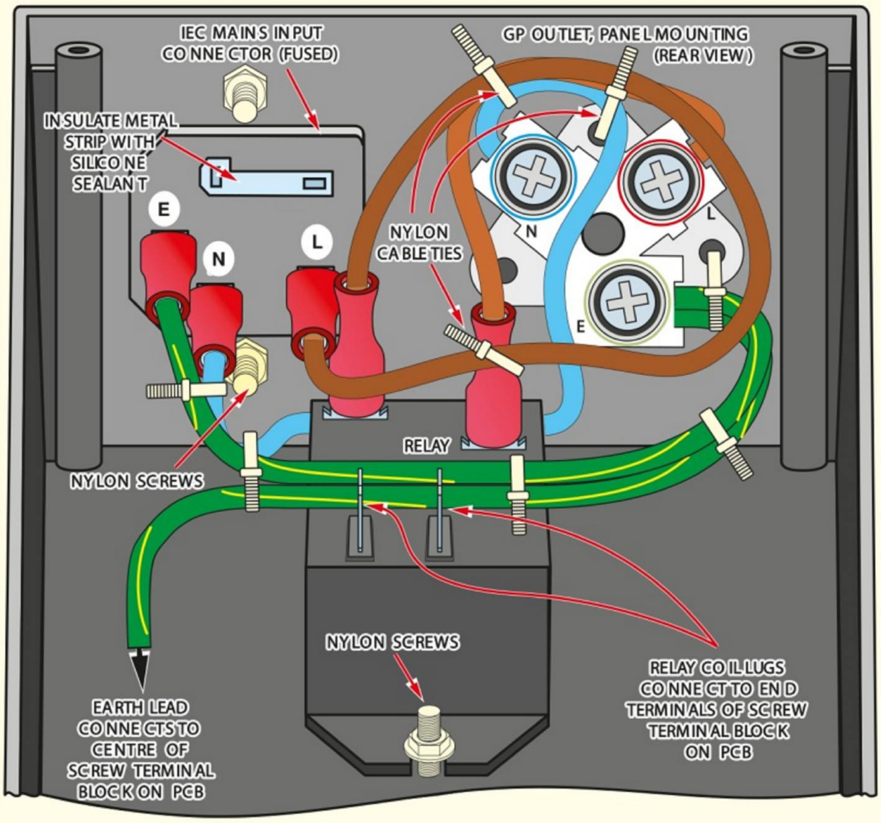
That way, the conductors end up connected in series, to form a 9-turn loop with its overall start at terminal 2 and its finish at terminal 11. This means that the two inner conductors of the output cable must also be connected to terminals 2 and 11, as shown.

You need to take special care with the shielding wires and braids, to ensure correct operation of the Faraday shield. Make sure that the loop cable's shield wire at the 'finish' end only is connected to screw terminal 12. The shield braid of the output cable is connected to the same terminal. In addition, a separate lead (shown green) must be run from this terminal and soldered to the copper on the underside of the PCB.

By contrast, the loop cable's shield wire is cut short at the 'start' end and is not connected to anything. It can be covered with a small piece of insulating tape if you wish, so that it cannot short against anything. Nothing is connected to screw terminal 1, which is just a spare connection.

Twist each pair of wires together before inserting them into the terminal block. For single wires, you will have to strip back a little more insulation, double the wire over and maybe add a little solder to make it thick enough to be securely gripped when the terminal screw is tightened.

Once it's all wired up, tighten the outer sleeve nuts of the cable glands to make the entry points watertight (add silicone sealant if necessary). The box lid can then be fitted, along with its



(1) INSULATE METAL STRIP ON IEC SOCKET WITH NEUTRAL-CURE SILICONE SEALANT
(2) SECURE IEC SOCKET & RELAY TO CASE WITH NYLON SCREWS, NUTS & WASHERS
(3) COVER MAINS WIRING WITH PRESSPAHN INSULATION

Fig.5: install the mains wiring as shown here. Be sure to use mains-rated cable for these connections and make sure that all connections are securely crimped. The wires must also be routed and strapped to the tabs on the mains outlet socket using cable ties as shown in the photo below, so that it's impossible for a wire to come adrift and contact other wiring.

Below: route the mains wires and secure them with cable ties as shown in this photo (note: Fig.5 doesn't show the exact routing for the sake of clarity). Be sure to insulate the metal strip on the IEC socket with silicone sealant.
See note on page 20

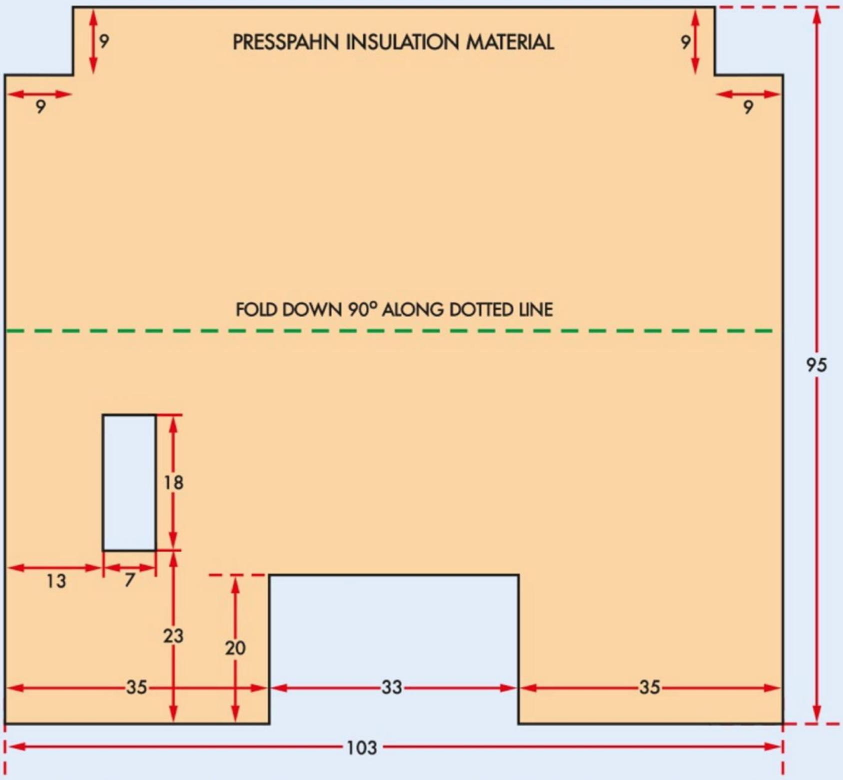
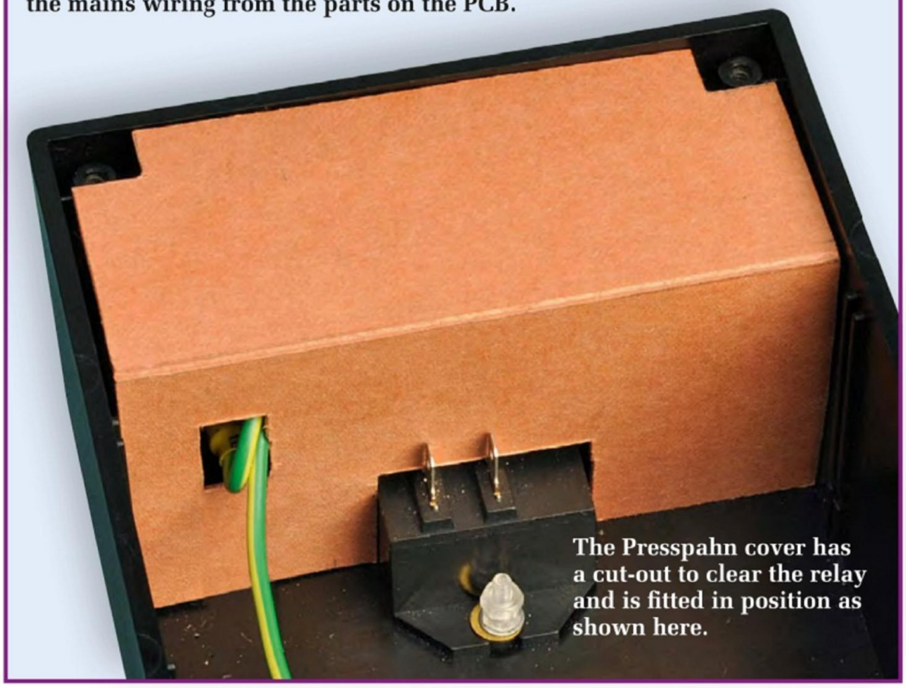


Fig.6: this diagram shows how to cut out and fold the Presspahn insulation material that's used to cover the mains wiring. Don't leave it out – it isolates the mains wiring from the parts on the PCB.



The Presspahn cover has a cut-out to clear the relay and is fitted in position as shown here.

neoprene gasket, and fastened in place using the screws supplied.

The only step remaining is to fit the other end of the output cable with a 5-pin DIN plug, to mate with input socket CON1 on the main *Driveway Sentry* PCB. Note that the two inner conductors must be soldered to pins 1 and 3 of the plug, while the screening braid goes to pin 2 (ie, the centre pin).

Preparing the case

The drilling details for the box and its lid are available in PDF format from the *EPE* website. These should be downloaded and printed out, after which the individual sections can be cut out and used as drilling templates (they can be temporarily attached to the box/lid using sticky tape).

Most of the holes can be made by simply drilling and (if necessary) reaming them to size. Be sure to always use a small pilot drill to start the larger holes, to ensure drilling accuracy.

The two holes for the mains input and output connectors at the righthand end of the box are inevitably more complex. These are best made by first drilling a series of small holes around the inside perimeter of the area to be removed. The holes can then be joined using a handheld jigsaw, after which the centre pieces can be knocked out and the edges de-burred and filed to a smooth finish using needle files.

Mains wiring

The next step is to mount the relay inside the case, with its switched output lugs nearest the adjacent end and the coil terminals towards the middle.

It should be secured using M3 × 12mm nylon screws, with metal flat and lock washers under nylon nuts on the top of the relay mounting flanges inside (do NOT use metal screws). A second nylon nut at each location is used to lock the first into position.

That done, use neutral-cure silicone sealant to insulate the exposed metal strip on the IEC input connector. That strip links the live input pin and the fuseholder, it runs at mains potential (230V AC) when power is applied. So insulating it is a good idea to prevent accidental contact.

You can now mount the IEC mains input connector and the mains output socket on the righthand end of the case. Use M3 × 12mm nylon screws to hold the IEC connector in place, along with flat washers and two nylon nuts on each screw.

Fig.5 and its accompanying photo show how the mains wiring is installed. Be sure to use mains-rated cable for all this wiring. You will need to crimp 6.3mm fully-insulated female spade connectors to the wires that go to the relay contacts and to the IEC connector.

In each case, it's a matter of stripping back about 5mm of insulation from the wire, then pushing it into the connector and crimping it with the tool. Check each crimp connection as it is made, to make sure it is securely terminated – you must not be able to pull the wire out of the connector.

Use double-crimp spade connectors

Note that the spade connectors used to terminate the mains wiring must be double-crimp types. This means that the metal collar inside each connector extends almost back to the wire entry hole.

That way, both the bared wires and the insulation are crimped by the metal surround, to give better retention. Don't use single-crimp types, which crimp the copper only, as the wire can more easily come loose.

Note that you must use a professional ratchet-driven crimping tool for this job. Don't even think about using a cheap, non-ratchet crimper; they are not up to the job for a project like this, as the pressure applied to the connectors will vary all over the place and this will result in unreliable and unsafe connections.

Note also that some IEC input connectors have 4.8mm terminals, in which case you must use 4.8mm spade connectors to suit. These should also be fully-insulated types or, if necessary, you can insulate them yourself using heatshrink tubing.

Once all the spade connectors have been fitted, plug the leads into the IEC connector, then connect the neutral lead to the mains socket. The lead from the live terminal on the IEC connector is terminated in a second spade connector and this connects to one of the relay output terminals. The other relay output terminal connects to the live terminal on the mains socket.

The two earth leads can now be run to the mains socket. One of these leads is run from the earth terminal on the IEC socket, while the second lead is routed back next to this lead and ultimately connects to the earth track of the PCB. You will need to make this latter lead about 250mm long.

Be sure to route the mains wires as shown in the accompanying photo (note: Fig.5 shows the connections but doesn't show the exact routing for the sake of clarity). Once all the connections have been made, use cable ties to strap the wires to the tabs on the mains socket (see Fig.5). Five more additional cable ties are also used to strap the wires together and should be installed as shown in Fig.5 and the photo.

Driveway Sentry: Parts List

1 PCB, code 03107121, available from the *EPE PCB Service*, size, 140mm × 84mm
1 UB2 jiffy box, size 197mm × 113mm × 63mm
1 110 × 100mm piece of Presspahn insulation material
1 PCB-mount mini piezo buzzer
2 panel-mount SPST pushbutton switches
1 PCB-mount 5-pin DIN socket (CON1)
1 2.5mm concentric DC input connector (CON2)
1 3-way PCB terminal block (CON3)
1 panel-mount fused IEC male input connector
1 M205 10A fuse
1 Mains outlet, flush panel mounting (see note on page 20)
1 12V SPST 20A chassis-mount mains relay (Ocean Controls RLY-008)
2 8-pin DIL IC sockets
2 14-pin DIL IC sockets
1 16-pin DIL IC socket
5 6.3mm fully insulated female spade connectors (see text)
2 fully insulated 4.8mm female spade connectors
1 150mm length of blue insulated mains-rated wire
1 200mm length of brown insulated mains-rated wire
1 400mm length of green/yellow mains-rated wire
2 120mm lengths of insulated hook-up wire
4 M3 × 25mm tapped spacers
9 M3 × 6mm machine screws
4 M3 × 12mm nylon screws
8 M3 nylon nuts
1 M3 hex nut
7 M3 star lockwashers
4 M3 flat washers
1 500Ω multi-turn trimpot (VR1)
2 500kΩ horizontal trimpots (VR2,VR3)
12 small nylon cable ties
1 150mm length tinned copper wire
1 3-way pin header
1 shorting link

Semiconductors
1 AD623 instrumentation amplifier (IC1)
1 LM324 quad op amp (IC2)
1 4011B quad CMOS NAND gate (IC3)
1 4060B CMOS counter (IC4)
1 7555 CMOS timer (IC5)
2 PN100 NPN transistors (Q1,Q2)
1 BC337 NPN transistor (Q3)
1 7806 +6V regulator (REG1)
1 5mm LED, green (LED1)
1 5mm LED, red (LED2)
1 1N5819 Schottky diode (D1)
1 1N4004 1A diode (D2)
1 1N4148 100mA diode (D3)

Capacitors
1 1000µF 25V RB electrolytic
1 220µF 16V RB electrolytic
1 47µF 16V RB electrolytic
1 47µF 25V RBLL low-leakage electrolytic
1 10µF 16V RB electrolytic
1 1µF MMC
2 470nF MKT polyester
1 220nF MKT polyester
1 150nF MKT polyester
10 100nF MMC or MKT polyester
2 22nF MKT polyester or greencap
1 10nF MKT polyester or greencap

Resistors (0.25W 1%)

1 470kΩ	4 10kΩ
2 220kΩ	4 4.7kΩ
1 180kΩ	1 1.5kΩ
2 100kΩ	4 1kΩ
1 68kΩ	1 560Ω
1 47kΩ	1 470Ω
1 27kΩ	2 100Ω
1 22kΩ	

Sensor Loop Assembly
1 IP65 sealed ABS enclosure, 115mm × 65mm × 40mm
1 blank PCB (ie, copper on one side), 104mm × 38mm
4 M3 × 6mm machine screws
1 12-way barrier screw terminal block, 96mm long
2 M3 × 15mm machine screws and nuts
3 cable glands (for 3-6.5mm cable)
3 nylon cable ties
1 25m length of screened 9-conductor 'computer cable'
1 10-30m length (to suit) of screened 2-conductor heavy duty microphone cable
1 5-pin DIN plug, line type
1 50mm-length spaghetti tubing

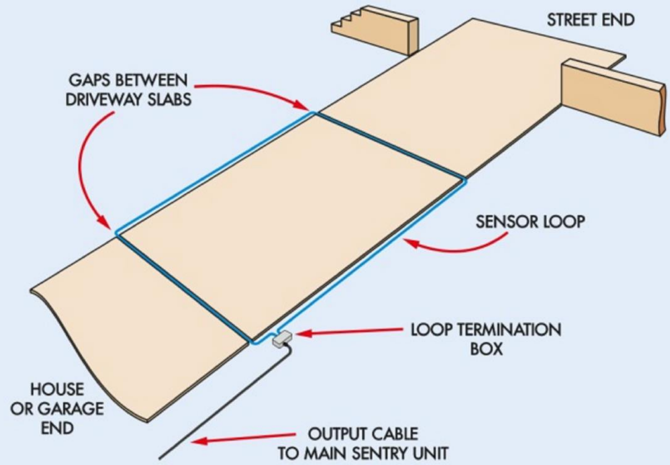


Fig.7: the loop sensor arrangement. The loop can either be buried just under the driveway or installed in the expansion slots of a concrete driveway, with the loop sides buried in a shallow trench. The loop termination box and the output cable should also be buried.

These cable ties are vital to ensure that an individual lead can't come loose and contact other terminals, even if the box receives a sudden jolt. In particular, be sure to strap the earth wires to the mains socket tab and strap the earth and neutral wires together at the IEC connector.

Presspahn cover

As shown in the photos, a Presspahn cover is used to physically isolate the mains circuitry from the low-voltage circuitry and the PCB. This fits vertically over the relay and is folded over the top of the IEC connector and mains socket to form a complete enclosure.

Fig.6 shows the dimensions of the Presspahn cover. It can be cut to shape using a sharp pair of scissors, while the hole for the earth lead that runs to the PCB can be cut out using a sharp hobby knife. The fold line is then lightly scored, after which the top section is folded down through 90°.

Check the mains wiring carefully before installing the Presspahn cover. It's a good idea to use a multimeter (set to ohms) to check all the connections between the IEC connector and the mains socket. The earth lead is critical – use the DMM to confirm continuity between the earth pin of the IEC socket and the earth of the flush-mounting mains socket.

Do the same for the two neutral connections (the two live terminals should be open circuit, since the relay contacts will be open). Check also to ensure there are no shorts between live and neutral on both the IEC connector and the mains socket, or between either of these two terminals and earth.

Once that's done, feed the earth lead that runs to the PCB through the hole in the Presspahn cover. The cover can then be slipped into position over the relay (see photos) and secured using some hot-melt glue or neutral-cure silicone sealant.

UK MAINS OUTLET SOCKET

This project was originally designed for the Australian market. While it is completely compatible with UK mains voltages, you will notice that the mains outlet socket pictured below is not a type used in the UK. We recommend you use an IEC female socket. However, you must ensure it will fit your chosen enclosure, and most important of all, if you are in any doubt as to the suitability of your choice of socket then you must seek advice from a trusted professional or someone with sufficient experience in wiring mains-related equipment – always be safe!

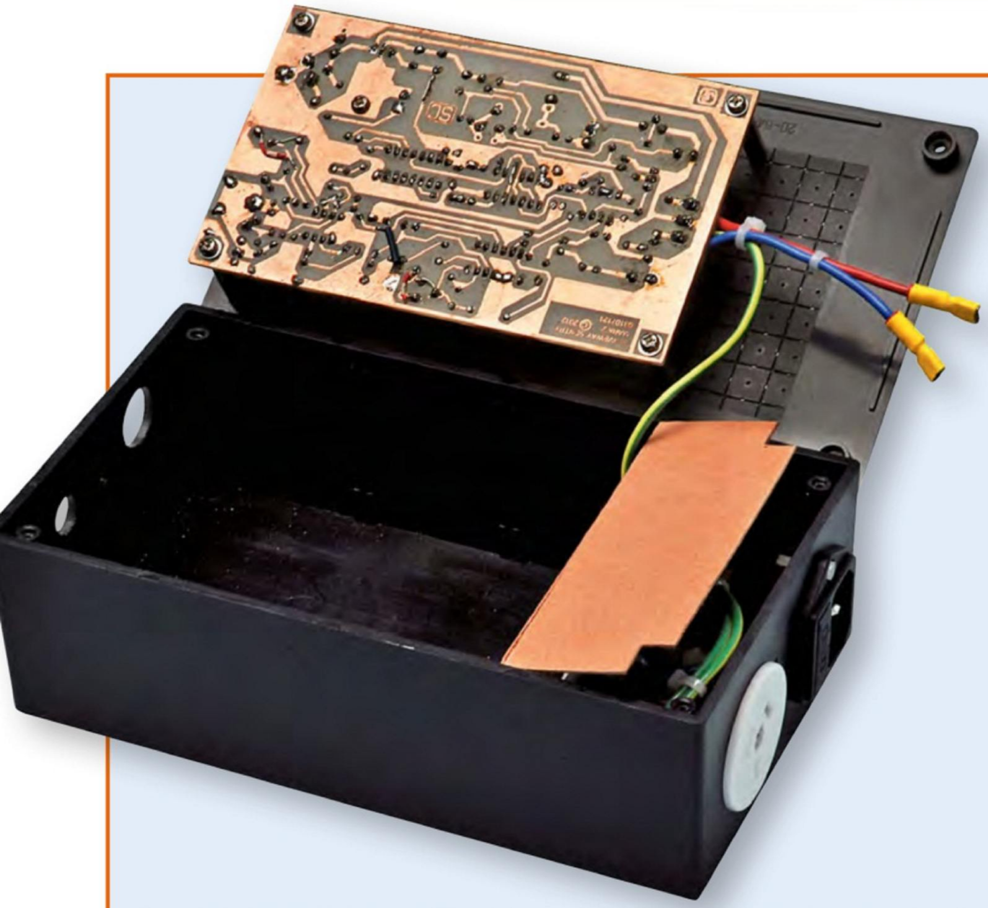
Final assembly

Now for the final assembly. The first step is to download the front panel artwork (in PDF format) from the *EPE* website. This should be printed out, laminated and attached to the front panel using double-side tape or silicone.

The holes in the panel artwork can then be cut out using a sharp hobby knife.

Once the panel is finished, mount the two pushbutton switches (S1 and S2), then attach four M3 × 25mm tapped spacers to the back of the box lid at the PCB mounting points. Secure

One end of the case carries the IEC input socket and the mains output socket (see note above) while the other end provides access to the loop input socket, the DC connector and the sensitivity trimpot (VR1).



The PCB is mounted on the lid of the case on four M3 × 25mm spacers. Make sure that the extension wires soldered to the switch terminals pass through their respective holes on the PCB, and don't forget to solder them.

these spacers using four M3 × 6mm machine screws.

That done, cut four 20mm lengths of 0.5mm tinned copper wire and solder these to the switch terminals. These form extension leads, which will later pass down through matching holes in the PCB when the latter is mounted on the spacers.

Next, cut two 80mm lengths of medium-duty hookup wire and crimp one end of each wire to a 4.8mm fully-insulated spade connector. Check that these connections are secure, then connect the opposite ends of these two leads to the terminal block on the PCB – see Fig.3.

The earth lead should also now be connected to the terminal block. Do the screws on the terminal block up nice and tight, then fit a cable tie to the three wires as shown in the photo. Another cable tie can then be used to bind the relay wires about 40mm from the connectors.

The PCB can be mounted on the spacers on the rear of the lid. Basically, it's just a matter of offering the board up to the lid while making sure that the extension leads from S1 and S2 pass through their corresponding PCB holes. At the same time, you have to make sure that LED1 and LED2 go through their matching holes in the lid.

Once everything is correct, secure the PCB to the stand-offs using M3 × 6mm screws and star washers. Do the screws up tightly, then solder the extension leads for switches S1 and S2 to their PCB pads.

The assembly can now be completed by connecting the two spade connectors to the relay coil terminals, then carefully lowering the PCB/lid assembly into the box. Note that it will be necessary to bend the leads from the terminal block straight up from the PCB so that they will clear the Presspahn cover. Make sure that the Presspahn cover is correctly positioned before securing the lid using the four small self-tapping screws supplied.

The *Driveway Sentry* in now complete and ready for installation and sensitivity adjustment. Both the sensitivity control (VR1) and the trigger sensitivity control (VR2) can be adjusted after the box is fully assembled, via small access holes (one in the lid and the other in the lefthand end of the case). The same goes for the alarm duration trimpot (VR3).

Switching other devices

If you don't wish to switch the mains, then the IEC socket, the flush-mount mains output socket and the mains wiring can all be omitted. You can then simply use the relay output contacts to switch a low voltage or to trigger some other piece of gear, eg, a burglar alarm.

Note, however, that it will still be desirable to earth the Faraday shield of the loop sensor, and this can be done by running a lead from the PCB earth terminal to a metal stake driven into the ground.

Sensitivity adjustment

To test the unit, the sensor loop must initially be laid on top of the driveway and connected to the main unit. You're then ready to adjust the sensitivity. It's simply a matter of setting VR2 to midrange and adjusting trimpot VR1 clockwise to make the *Driveway Sentry* more sensitive, or anticlockwise to make it less sensitive.

This will have to be done on a trial and error basis, with a vehicle driven over the sensor loop after each adjustment. The best setting is where it reliably detects the smallest moving vehicle likely to enter or leave the driveway, but don't make it more sensitive than necessary. If you simply adjust VR1 for maximum sensitivity (ie, fully clockwise), the unit may be prone to giving false alarms due to passing radio transmitters or mobile phones, or during electrical storms.

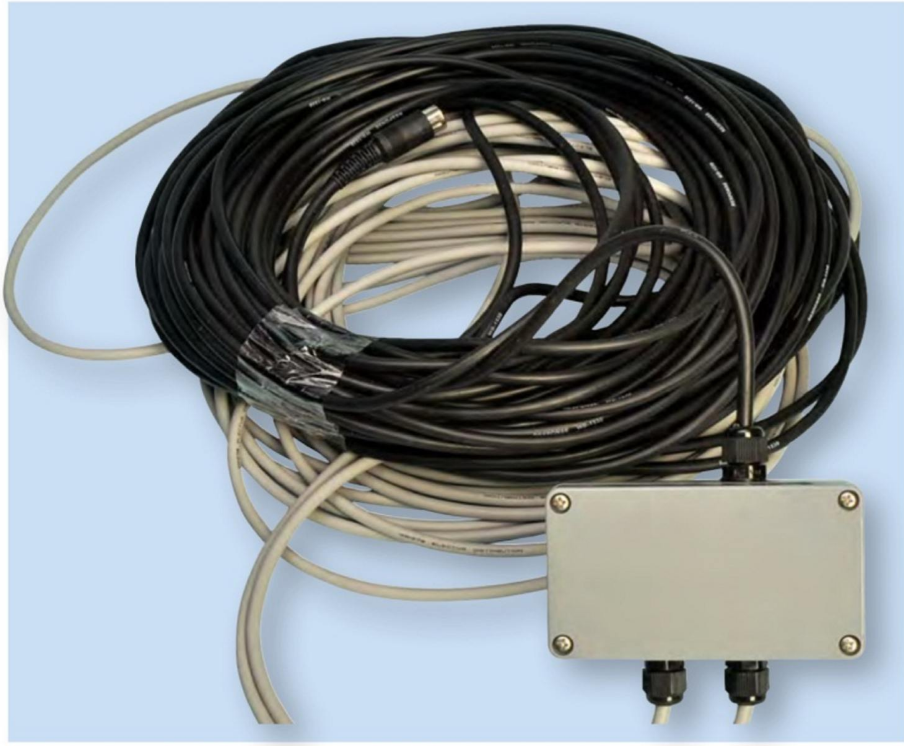
Note that the loop direction will affect the sensitivity. If you cannot get reliable triggering, reverse the loop by turning it over. This means that you must test the complete unit before burying the loop.

VR2, the trigger sensitivity adjustment, is basically a back-up, and is normally left in the midrange position. It need only be moved from this position if you run out of range with VR1.

Sensor loop installation

The remote sensor loop can either be buried under your driveway (eg, under pavers) or it can be installed in the expansion joints of a concrete driveway.

As shown in Fig.7, two of its opposite sides lie in the narrow gaps between the concrete driveway slabs, while the other two sides run alongside the enclosed slab on either side. The loop termination box can be located adjacent to one side, with the output cable running away to the main control box inside your house.



This is the completed loop termination box, together with the sensor loop cable (light grey) and the extension cable (black) that runs back to the main unit. Make sure that the box is properly sealed against moisture.

In practice, the loop termination box can be buried and the output cable run in a shallow trench back to the house, so that it doesn't get damaged. Make sure that the cable glands have all been properly sealed using silicone before burying the loop termination box, to prevent water damage.

If you are on a rural property, the loop sensor can simply be buried under the driveway in a shallow rectangular trench.

Using it

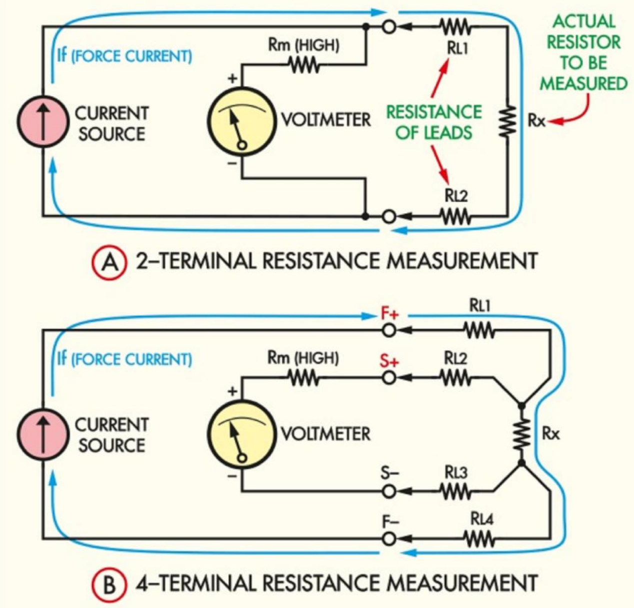
When the *Driveway Sentry* is armed and detects movement, it immediately produces an alarm sound from the buzzer and operates the relay. The relay contacts can be used to switch on a security floodlight, other lighting or perhaps a siren. The Alarm Duration can be set by adjusting VR3 using a screwdriver through the front-panel access hole.

Finally, note that any fixed mains wiring to lights or other mains-powered items should be installed by a qualified electrician. *EPE*

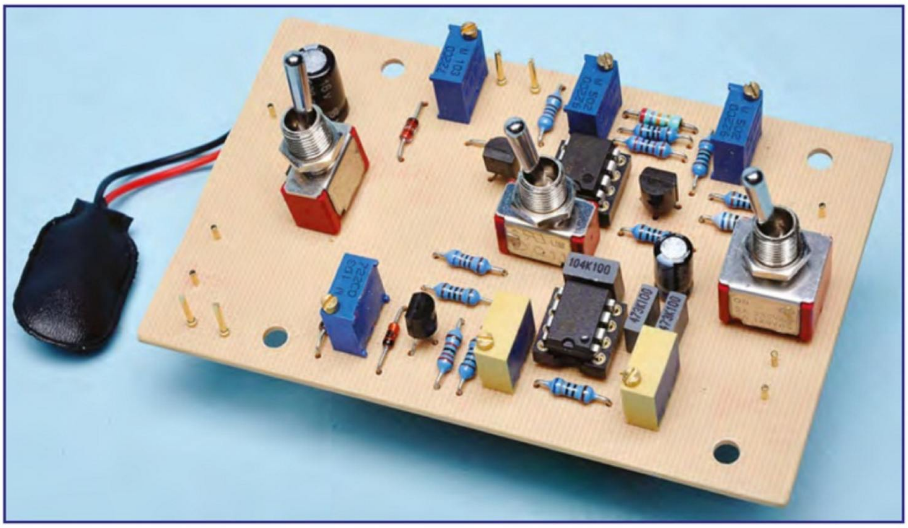
Do you occasionally need to measure very low resistances accurately, but don't have access to an expensive benchtop milliohm meter or DMM? This low-cost adaptor will let you use almost any DMM to make accurate low-resistance measurements.

Milliohm Meter Adaptor for DMMs

By Jim Rowe



The top diagram (Fig.1a) shows the way resistance is measured in 'normal' meters (ie, two-terminal). The lower diagram (Fig.1b) shows how higher accuracy is achieved with four-terminal measurement, especially for low resistances. This is the approach taken in this *Milliohm Adaptor.*



With the exception of the terminals and battery, all components mount on a single PC board.

WHEN IT COMES TO MEASURING low resistances (ie, below about 10Ω) with any significant accuracy, very few standard handheld digital multimeters are of much use. Only the top-of-the-range models offer any real performance in this area.

And when you want to measure even lower resistances – less than one ohm – even some of these drop out of contention. It's really only the most expensive benchtop models that will provide milliohm-level measurements as a matter of course.

This doesn't pose much of a problem for most of us, most of the time, because accurate low-value resistance measurements are not needed often.

But sometimes you do need low-ohm accuracy, eg, when matching the values of low-value resistors used for current sharing in amplifier output stages, or when you need to make up a low resistance current shunt for a panel meter.

That's when you need this *Milliohm Meter Adaptor.* It's self-contained and designed to act as a very low resistance measuring 'front end' for almost any standard DMM.

It works by converting low resistance values into a directly proportional DC voltage (nominally 0-1.000V), so the DMM is simply set for its 1V or 2V DC voltage range, the range where most DMMs have their highest accuracy.

So when the *Adaptor* is being used to measure a very low resistance, the resistance value is simply read out on the DMM in millivolts.

Actually the *Adaptor* provides two measurement ranges, one is a '0-1.0Ω' range, where it converts milliohms directly into millivolts (so 125mΩ becomes 125mV, for example). The other is a '0-10Ω' range, where it converts tens of milliohms into millivolts – so 2.2Ω (2200mΩ) becomes 220mV.

So, reading the low-value resistances on your DMM doesn't require much mental arithmetic.

Now at this stage you're probably thinking this: if a low-cost *Adaptor* like the one we're describing here can make this kind of very low resistance measurement relatively easily, why don't most DMMs provide such ranges?

That's because there is a catch: in order to measure low resistances accurately, you have to use a four-terminal measurement approach, rather than the two-terminal approach used in the majority of DMMs.

So, before we look at the new *Adaptor* and the way it works, we'd better explain why it needs to make four-terminal measurements.

Why four terminals?

To understand what we're talking about here, look first at the upper resistance measurement circuit in Fig.1(a). This shows the kind of two-terminal measurement used by most DMMs to measure resistances.

As you can see, it's quite straightforward: a constant current source forces a current, *If,* through the resistance to be measured (*Rx*), which is connected to the meter's test terminals. The voltmeter section of the DMM then measures the voltage drop across the test terminals, which is directly proportional to the resistance between the terminals – because according to Ohm's law this voltage is given by E = *If* × *Rx*.

Note that the voltmeter has a very high multiplier resistance (*Rm*), so it is assumed to draw virtually no current.

The drawback with this approach is that as shown, our unknown resistance *Rx* isn't the only resistance between the two test terminals – there's also the resistance of the test leads, *RL1* and *RL2*. These are effectively in series with *Rx*, so the voltage drop across them as a result of *If* flowing through them will simply be added to the drop across *Rx*. The resistance measured by the DMM will therefore be (*Rx* + *RL1* + *RL2*), rather than just *Rx* itself.

Now, from a practical point of view this doesn't introduce much error

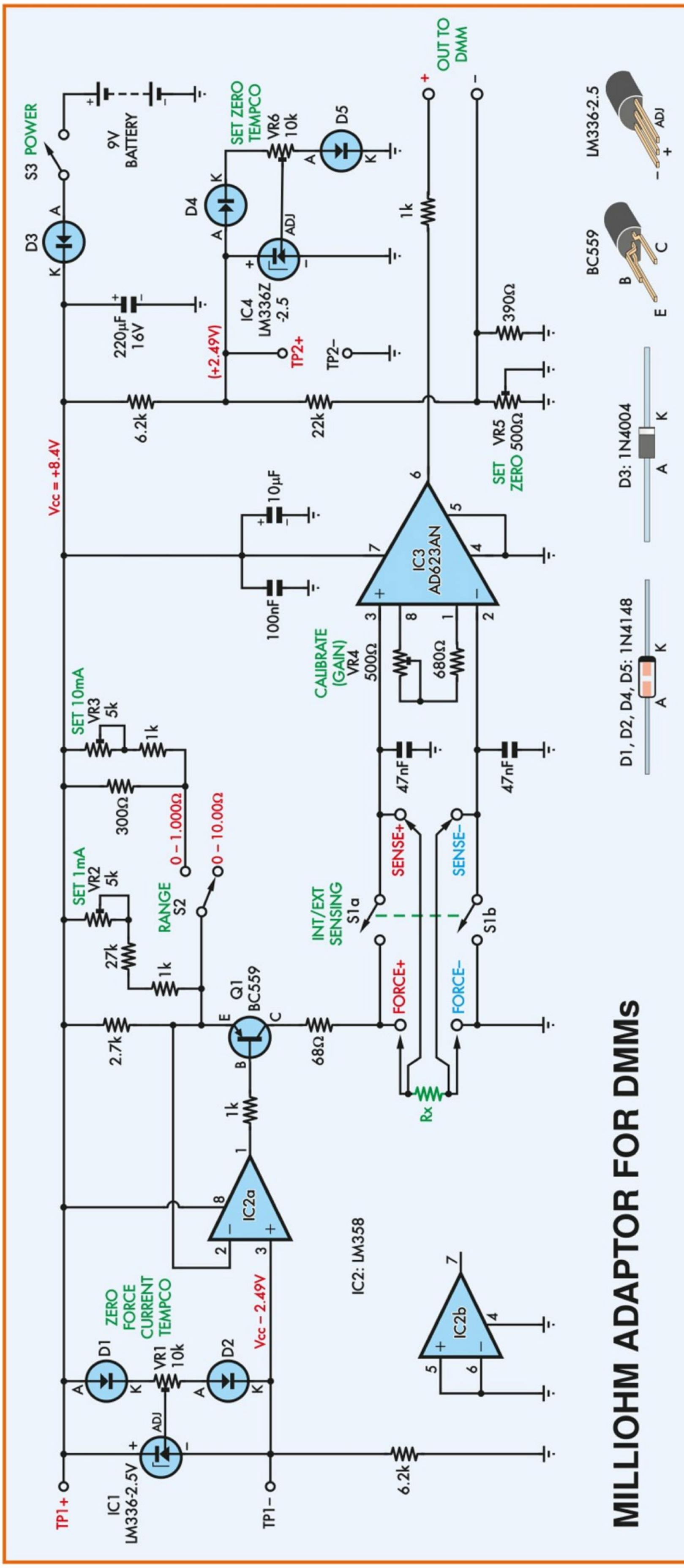


Fig.2: the complete schematic. The circuitry at upper left forms a regulated source of force current, while that at lower right is a DC amplifier with a gain of exactly 100.

when you're measuring resistances over 10Ω or so (with fairly short test leads). It's usually not too difficult to keep the test lead resistances down to a few tens of milliohms (which is less than 1% of the value of *Rx*). But when you're trying to measure somewhat lower resistances, the errors can be quite significant.

For example, if the resistance you're measuring is 1Ω, two test leads, each with a resistance of 30mΩ, will increase the total resistance across the terminals by 60mΩ or 0.06Ω, giving a measurement error of +6%.

Now consider what happens when we use the four-terminal measurement approach shown in Fig.1(b). Here we still force a known current through the unknown resistor *Rx* and measure the voltage drop across it as before, using a high-resistance voltmeter. But in this case, the force current *If* is fed to *Rx* via one pair of terminals F+ and F–, while the voltmeter is connected across *Rx* via a second set of 'sensing' terminals S+ and S–.

As you can see, the F+ and S+ terminals are connected to one end of *Rx* via separate leads, while the F– and S– terminals are connected to the other end, also via separate leads. So there are now four test leads, with resistances *RL1, RL2, RL3* and *RL4*.

But how does this extra complexity help?

Look carefully and you'll see that although the force current *If* still flows through force lead resistances *RL1* and *RL4*, the voltage drops across these resistances now don't matter because the voltmeter's sensing leads are connected directly across *Rx* itself – ie, we now only measure the voltage drop across *Rx* alone.

And the sensing lead resistances *RL2* and *RL3* don't cause any problems either, because they're simply in series with the very high resistance of the voltmeter circuit (and they carry only its tiny measurement current).

So that's why changing over to four-terminal resistance measurement gives much better accuracy, especially when you're measuring very low resistances.

Circuit description

Now that you understand the basic concept of four-terminal resistance measurement, let's now take a look at the circuit of the new *Milliohm Measuring Adaptor* and the way it works in detail.

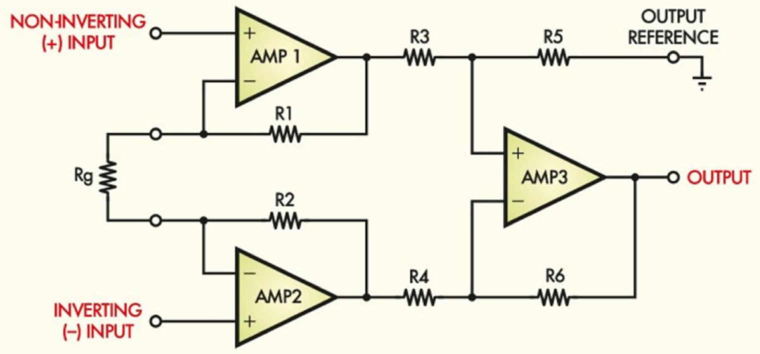


Fig.3: an instrumentation amplifier consists of three internal op amps, two used as matched input buffers for the third one (AMP3) connected as a difference amplifier.

The schematic diagram (Fig.2) has four measuring terminals just to the left of centre labelled FORCE+, FORCE–, SENSE+ and SENSE–. It will help in understanding the way the circuit operates if you regard all of the circuitry above and to the left of the force terminals as comprising the force current source, while all of the circuitry to the right of the sensing terminals comprises the voltmeter section. (It's actually a DC amplifier with its output connecting to the voltmeter section of a DMM.)

Before we get going, you've probably noticed already that the two poles of switch S1 are wired so that the two positive terminals and the two negative terminals can be connected together if desired, for 'internal sensing'.

This switch has been provided purely to allow the adaptor to be used for making 'quick and dirty' (ie, less accurate) two-terminal measurements on components which can be connected directly to the force terminals, without any test leads as such.

So, for the rest of this discussion, you should regard both poles of S1 as open, just as they are shown in the schematic. This 'external sensing' position of S1 is the one used for accurate four-terminal measurements, with Rx connected to all four terminals as shown.

Let's now turn to the circuitry used to provide the force current for our measurements. This is the section at upper left of the schematic involving IC1, IC2a and transistor Q1. Although it may look a bit complex, it's really quite straightforward if you break it into sections.

IC1, together with D1, D2, the 6.2kΩ resistor and trimpot VR1, form a regulated voltage source which establishes a voltage difference of 2.490V between test points TP1+ (the *Adaptor's* supply rail) and TP1–. Why 2.490V? Simply because when the LM336-2.5 reference used for IC1 is adjusted to have this voltage drop, the temperature coefficient or 'tempco' of its voltage drop is very close to zero – staying constant over a wide temperature range (0-50°C).

IC2a and Q1 are used together with their associated components to generate a constant force current through the adaptor's force terminals, using the 2.490V voltage drop established by IC1 as its reference. They do this very simply: IC2a increases the base current to Q1 until the voltage level at Q1's emitter (fed to pin 2 of IC2a) matches the voltage level fed to pin 3 by IC1. The base current is then stabilised at this level, and this in turn stabilises the transistor's emitter and collector currents as well.

Since the voltage level at the emitter of Q1 is set by the current flowing in the resistance between the emitter and the positive supply rail, we can set the force current level by adjusting the emitter resistance.

We provide the adaptor with two measuring ranges by using switch S2 and the various resistors in Q1's emitter circuit to provide two different preset emitter resistances, corresponding to two preset force current levels.

For example, when S2 is in the position shown, the transistor's emitter resistance consists of the fixed 2.7kΩ, 1kΩ and 27kΩ resistors, together with trimpot VR2. By adjusting VR2, we are thus able to set the total effective emitter resistance to 2.490kΩ, which sets the collector current of Q1 (ie, the force current) to a level of 2.49V/2.49kΩ, or exactly 1.000mA.

Parts List – Milliohm Adaptor For Digital Multimeters

- 1 PCB, code 04102101, available from the *EPE PCB Service*, size, 91mm × 57mm
- 1 UB3 utility box, 130mm × 68mm × 44mm
- 2 8-pin machined-pin DIL IC sockets
- 1 DPDT mini toggle switch (S1)
- 2 SPDT mini toggle switches (S2, S3)
- 2 4mm binding posts, red
- 2 4mm binding posts, black
- 1 4mm banana jack socket, red,
- 1 4mm banana jack socket, black
- 4 M3 × 15mm tapped spacers
- 8 M3 × 6mm machine screws
- 1 9V battery, alkaline or lithium
- 1 9V battery snap lead
- 4 self-adhesive rubber feet
- 12 1mm-diam. PCB terminal pins
- 1 200mm length red insulated light duty hook-up wire
- 1 200mm length black insulated light duty hook-up wire

Semiconductors
- 2 LM336Z-2.5 +2.5V regulators (IC1, IC4)
- 1 LM358 dual op amp (IC2)
- 1 AD623AN instrumentation amplifier (IC3)
- 1 BC559 PNP transistor (Q1)
- 4 1N4148 diodes (D1,D2,D4,D5)
- 1 1N4004 1A diode (D3)

Capacitors
- 1 220µF 16V RB electrolytic
- 1 10µF 16V RB electrolytic
- 1 100nF 100V MKT metallised polyester
- 2 47nF 100V MKT metallised polyester

Resistors (0.25W 1% unless specified)

1 27kΩ	1 22kΩ	2 6.2kΩ
1 2.7kΩ	4 1kΩ	1 680Ω
1 390Ω	1 300Ω	1 68Ω

- 2 10kΩ 25T vertical trimpot (code 103) (VR1,VR6)
- 2 5kΩ 25T vertical trimpot (code 502) (VR2,VR3)
- 2 500Ω 25T vertical trimpot (code 501) (VR4,VR5)

Alternatively, if S2 is switched to the '0-1.000Ω' position, the 300Ω and 1kΩ fixed resistors plus trimpot VR3 are connected in parallel with the

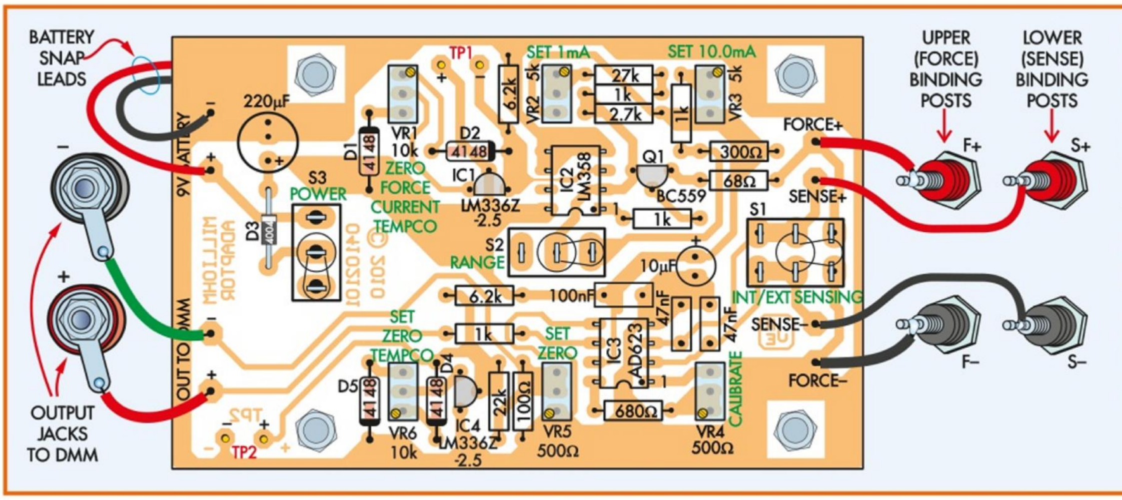


Fig.4: follow this component overlay (along with the same-size photo at right) when assembling your *Milliohm Adaptor*. The two sets of 'horizontal' PC pins at the top centre and bottom left of the PC board are test points TP1 and TP2, and are not normally connected.

existing emitter resistances. By adjusting VR3, we are now able to set the total effective emitter resistance to 249.0Ω. This sets the collector current of Q1 to a level of 2.49V/249Ω, or exactly 10.00mA.

So switch S2 allows us to set the adaptor's force current level to either 1.000mA or 10.00mA, and that's how we provide its two measuring ranges.

As mentioned earlier, the section of the circuit to the right of the sensing terminals (SENSE+ and SENSE–) acts as a DC amplifier which takes the small voltage drop across our unknown resistor *Rx* (produced by the force current flowing through it) and amplifies it before feeding it out to the DMM for measurement.

We use an AD623AN instrumentation amplifier (IC3) for this job, because the requirements are fairly stringent: we need high and stable DC gain (100 times) coupled with high input impedance, very low input offset and high common-mode rejection. These requirements are most easily met by using an instrumentation amp like the AD623AN.

By the way, if you're not familiar with instrumentation amps, a simplified version of their most common internal configuration is shown in Fig.3.

As you can see, they consist of three conventional op amps, with the third one (AMP3) operating as a difference amplifier.

The other two op amps are configured as input buffers, to give each input of AMP3 a high input impedance. At the same time, the gain of the two input buffers is carefully matched by laser trimming of their feedback resistors R1 and R2. This matching is also done for the resistors around AMP3 and the end result is not only very low input offset, but very high common-mode rejection as well.

Because of the balanced nature of the two input buffers, their gain (and that of the complete instrumentation amp) can be set by varying a single external resistor, Rg.

The 680Ω fixed resistor and trimpot VR4 connected between pins 1 and 8 of IC3 are used to adjust the gain of the amplifier stage to exactly 100 times (ie, they correspond to Rg in Fig.3). As a result, VR4 is used to calibrate the adaptor/DMM combination for the most accurate readings.

As yet, we haven't mentioned IC4 – which as you have probably noticed already is a second LM336Z-2.5 voltage reference, just like IC1.

It's also connected in the same way as IC1, with diodes D4 and D5 plus trimpot VR6 used to allow its voltage drop to be set to 2.490V – providing a near-zero temperature coefficient. So its function is to provide a temperature-stabilised source of +2.490V (with respect to ground in this case), measurable between test points TP2+ and TP2–.

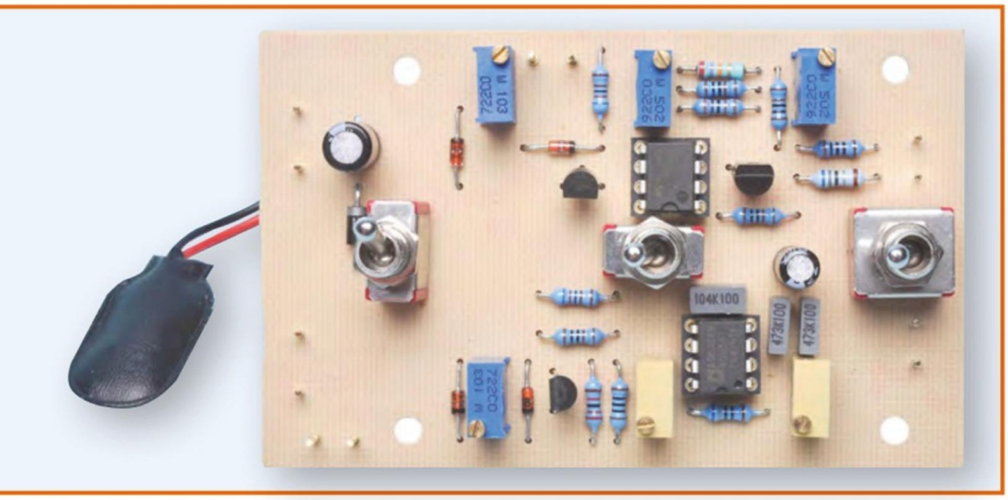
Why do we need another source of stabilised DC voltage? Because although the AD623AN instrumentation amp is particularly good in terms of very low input offset, like all components in the real world, it isn't perfect.

So in order to set the output to the DMM to exactly 0.000V when IC3 has zero input voltage (ie, when the SENSE+ and SENSE– terminals are shorted together and also connected to ground), we need to vary the DC voltage on the negative output terminal over a very small range relative to circuit ground.

That's the purpose of trimpot VR5, which forms the lower leg (together

Resistor Colour Codes

❏	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	1	27kΩ	red violet orange brown	red violet black red brown
❏	1	22kΩ	red red orange brown	red red black red brown
❏	2	6.2kΩ	blue red red brown	blue red black brown brown
❏	1	2.7kΩ	red violet red brown	red violet black brown brown
❏	4	1kΩ	brown black red brown	brown black black brown brown
❏	1	680Ω	blue grey brown brown	blue grey black black brown
❏	1	390Ω	orange white brown brown	orange white black black brown
❏	1	300Ω	orange black brown brown	orange black black black brown
❏	1	68Ω	blue grey black brown	blue grey black gold brown



with the 390Ω resistor across it) of a voltage divider connected across the stabilised 2.490V source provided by IC4. The upper leg of the divider is the 22kΩ resistor, so by adjusting VR5 we are able to vary the voltage level at the negative output terminal between 0V and approximately +25mV. This may seem small, but it's quite sufficient to allow setting of the *Adaptor's* output to zero – within a tiny fraction of a millivolt.

Power supply

The complete adaptor circuit operates from a single 9V alkaline battery, with switch S3 used to control power, and diode D3 to prevent circuit damage in the event of the battery being connected with reversed polarity. This means that all of the adaptor operates from the unregulated +8.4V (nominal) supply rail. We can do this because IC1 and IC4 stabilise the only critical reference voltages.

Incidentally, the battery drain of the adaptor when operating on the 0-1.000Ω range is around 14mA, dropping to around 4mA on the 0-10.00Ω range. The difference is of course due to the change in force current level.

Construction

As you can see from the photos, the adaptor is housed with its 9V battery in a standard UB3-size jiffy box (130mm × 68mm × 44mm). Inside the box, all the parts except for the measurement terminals and output sockets are mounted directly on a small PCB, coded 04102101 and measuring 91mm × 57mm. The PCB is available from the *EPE PCB Service.*

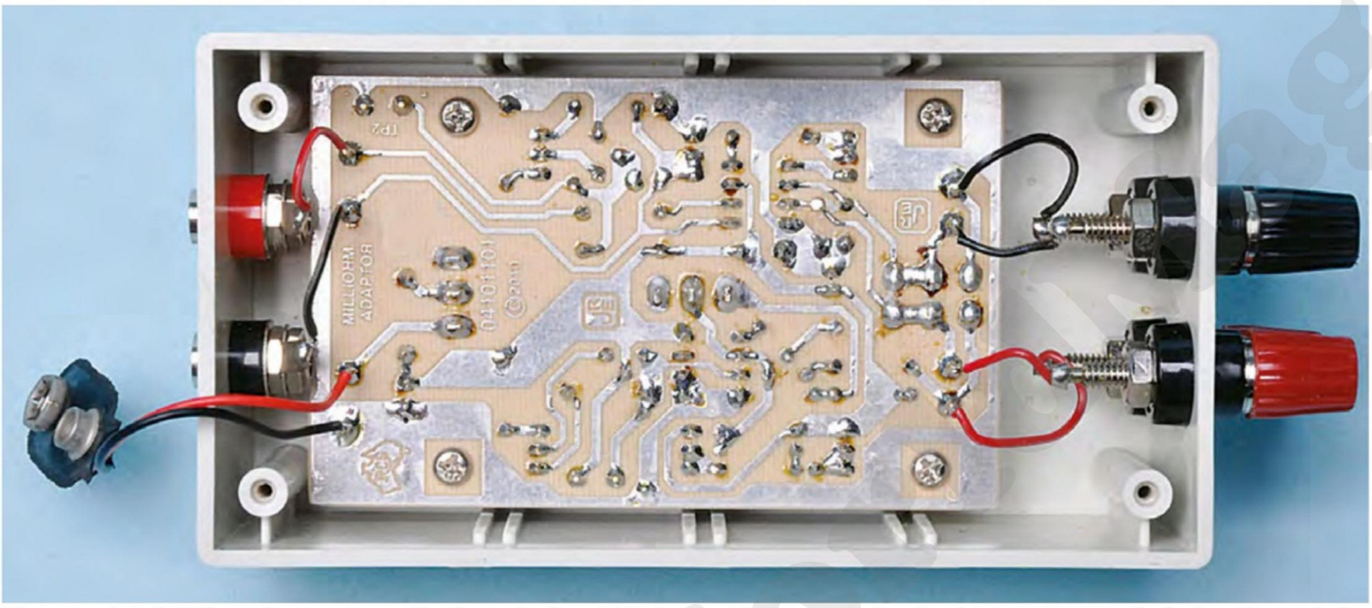
The PCB is supported inside the box using four M3 × 15mm tapped spacers. The four measurement terminals are mounted at one end of the box, while the two output sockets are mounted at the other end.

Fig.4 and the accompanying photos show the assembly details. There are no wire links to be fitted, but there are 12 PCB terminal pins – four for the two pairs of test points and the other eight for the off-board connections to the measurement terminals, output sockets and battery snap leads.

Fit these pins first, taking care to fit the test point pins from the component side of the board and the other pins from the copper side. This makes it easier to connect to the latter pins after the board assembly is fitted into the box.

After the terminal pins are fitted and soldered in place, you can fit the sockets for IC2 and IC3. Follow these with the three mini toggle switches and note that you may need to use a small needle file to convert the matching holes in the board into a rectangular shape to accommodate the connection tags on the rear of the switches. The tags of each switch need to pass down through the board holes as far as they'll go, before soldering to the pads underneath.

With all three switches fitted, the next components to add are the fixed resistors. Make sure you fit these in their correct positions, as shown in the overlay diagram, otherwise your



The completed PC board mounts upside-down in the utility box so that its switches (and trimpot access holes) go through the bottom of the case – which, with the addition of a suitable label, becomes the front panel. The box lid, with adhesive rubber feet, then becomes the base of the project (see also Fig.6, overleaf).

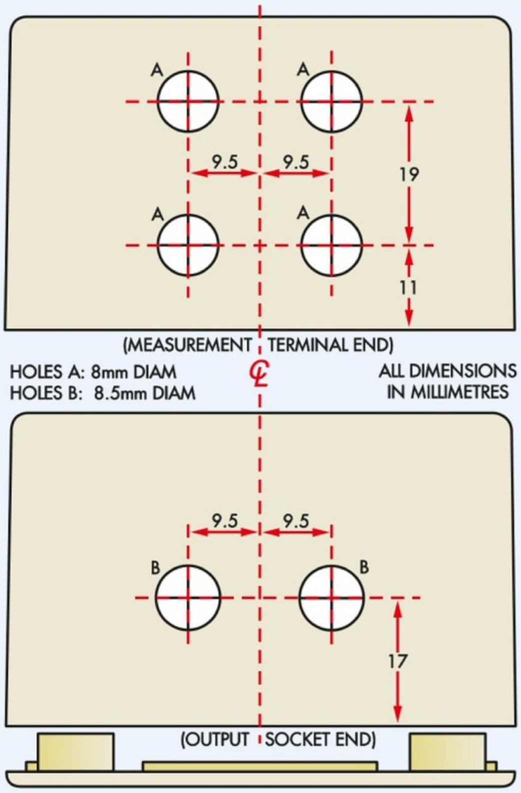


Fig.5: drilling detail for the two ends of the UB3 utility box. You will also need to drill nine holes in the 'bottom' of the box – use a photocopy or printout of the front panel artwork (Fig.7 overleaf) as a drilling template.

Adaptor will not work correctly. It's a good idea to use your DMM to check the value of each resistor before it's fitted in place and soldered.

Follow the fixed resistors with the five capacitors. Three are unpolarised MKT metallised polyester types, and the remaining two are a polarised electrolytic type. Be sure to fit the latter with the polarity shown on the parts layout diagram (Fig.4).

Next fit the trimpots, which are all miniature multi-turn types with their adjustment shaft in one top corner. Be careful in fitting these, not only to fit the correct value pot in each position (there are two 10kΩ pots, two 5kΩ pots and two 500Ω pots) but also to make sure that each pot is oriented the correct way around, as shown on Fig.4.

VR1, VR2 and VR3 are oriented with their adjustment shaft at upper right, while the other three trimpots have the opposite orientation, with the adjustment shaft at lower left.

If you don't mount them this way, you won't be able to adjust them easily when the board assembly is later mounted inside the box.

Semiconductors

The final components to fit to the board are the semiconductors, starting with the five diodes. Take care to fit them the correct way around. Note too that D3 is a 1N4004 diode rated at 1A, while the others are smaller 1N4148 diodes.

After the diodes are in place, fit transistor Q1 and the two TO-92 voltage reference ICs, IC1 and IC4, again watching their orientation. Your board assembly will then be complete, apart from the two plug-in ICs.

We suggest that you only plug in IC2 at this stage. **IC3 is best left out until the initial setting-up has been done, because it's a fairly expensive chip and could possibly be damaged before the force current levels have been set correctly.**

For the moment, just place the nearly completed PCB assembly aside while you prepare the box by drilling the various holes that are needed.

There are no holes to be drilled in the box lid; it is used purely as a screw-on project base. All of the 'works' are mounted inside the box proper, as you can see from the photos and the side view assembly diagram (Fig.6).

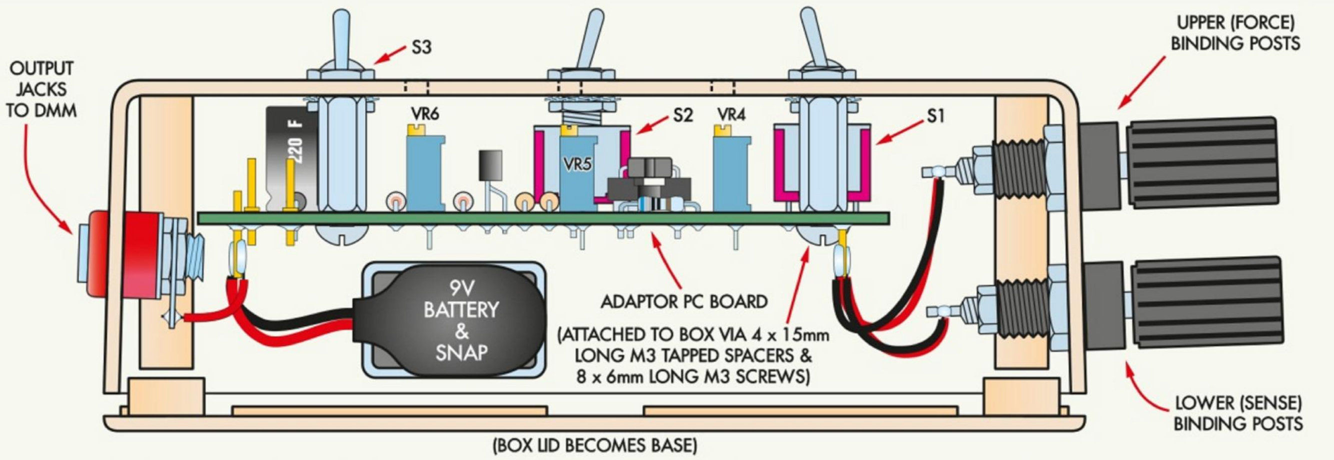


Fig.6: this 'X-ray' view through the utility box side shows how it all goes together. Not seen here are the two red binding posts which are directly behind the black posts. The 9V battery could be mounted in its own holder or, if you want to save expense, do as we did – simply hold it in place with some duct tape!

There are several holes to be drilled in the box bottom, as this becomes the *Milliohm Adaptor's* top/front panel. A photocopy of the front panel artwork (or a printout of the panel artwork file from the *EPE* website) can be used as a template for locating and drilling these holes. The small holes should all be 3.5mm diameter, while the three larger holes (for the switch ferrules) should all be 7mm diameter.

The location and sizes of the holes in the ends of the box are shown in the diagram of Fig.5. Once these holes have been drilled (and if necessary reamed to size), you can fit the measurement terminals and the output jack sockets into them, taking care to tighten their nuts firmly so they won't come loose in use.

Before your *Adaptor's* PCB assembly can be fitted into the completed box, it needs to have some of its initial set-up adjustments made. These are done with the PCB assembly on the bench, and powered by either its own 9V battery or some other suitable 9V DC power supply.

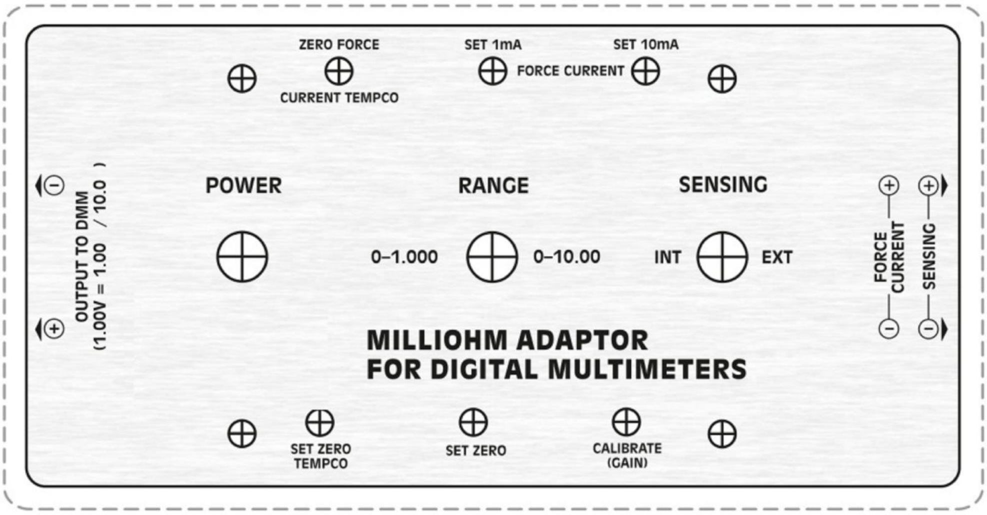


Fig.7: same-size front panel artwork. This can be photocopied (or printed out from the file on the *EPE* website) and laminated before gluing onto the UB3 box base and drilling the three switch holes and six pot access holes.

Initial setup adjustments

All the adjustments can be made using a standard DMM, which can be the one you'll be using the *Milliohm Adaptor* with later, if you wish.

The first adjustments to be made are of the two temperature coefficient zero pots, VR1 and VR6. For both of these adjustments you use the DMM set to its 0-4V, 0-10V or 0-20V DC range.

To adjust VR1, you simply connect the DMM test leads to test points TP1+ and TP1– and then adjust VR1 with a small screwdriver until you get a reading of 2.490V (or as close to this figure as you can get). That done, you can transfer the DMM leads to TP2+ and TP2–, and adjust VR6 in the same way to get a reading of 2.490V.

That completes the first two adjustments and you are now ready to make the next two. For these, the DMM is switched to a low DC current range and this time its leads are connected to the FORCE+ and FORCE– terminal pins at the right-hand end of the board – with the positive lead connected to FORCE+ and the negative lead to FORCE–.

That done, switch S2 so that its toggle is towards the right (ie, in the 0-10.00Ω position). Your DMM should give a current reading somewhere in the vicinity of 1mA. If necessary, change the DMM's range to provide the best possible resolution, then adjust trimpot VR2 until you get a reading as close as possible to 1.000mA (= 1000μA).

Once this has been achieved, switch S2 to its other position (0-1.0Ω), which should cause the current reading to jump to a higher figure – around 10mA. Again, adjust the DMM range if necessary to get optimum reading resolution and then adjust trimpot VR3 to bring the reading as close as possible to 10.00mA.

That completes the initial setup adjustments, now you're almost ready to fit the PCB assembly inside the box. Before doing so, turn off the power using S3, remove the 9V battery from its snap lead and attach the four M3 × 15mm tapped spacers to the top of the board using four M3 × 6mm screws passing up from underneath. Tighten the screws firmly to make sure they don't come loose later.

Now take IC3 from its protective packaging and plug it carefully into its socket at lower right on the board, making sure that it's oriented as shown on Fig.4.

Final assembly

To begin the final stage of assembly, remove the upper mounting nut from each of the three toggle switches (S1-S3) and then adjust the lower nuts to bring the lockwasher and flat washer on each ferrule up to a level as close to 15mm above the top of the board as you can – that is, level with the tops of the four board mounting spacers. You might find a small steel rule helpful here.

Now, with the upper nuts still off the switch ferrules, the idea is to hold the PCB assembly upright while you lower the main part of the case down over it (with the correct orientation, of course!) until the switch toggles and then the tops of their threaded ferrules pass up through their matching holes in the box.

They should be protruding by about 1.5-2mm by the time the tops of the mounting spacers are up against the upper inside of the box, allowing you to attach the three remaining switch nuts to each switch ferrule to hold everything together. Then you'll be able to fit the four remaining M3 × 6mm screws to secure the board mounting spacers to the box.

The screws should be tightened quite firmly, whereas the switch nuts need only be finger tight.

The final step in assembling your *Milliohm Adaptor* is to upend the box and fit the short connecting wires which connect the measurement binding posts and output sockets to their corresponding terminal pins on the PCB. The connections for each of these wires is shown in the overlay/wiring diagram, so if you follow this methodically you shouldn't make any mistakes.

By the way, there's no need to use heavy-gauge wire for any of these wires – ordinary insulated hookup wire is fine, because of the four-terminal measurement system.

Once these wires have all been fitted, you can mount the 9V battery on the inside lid/bottom of the box,

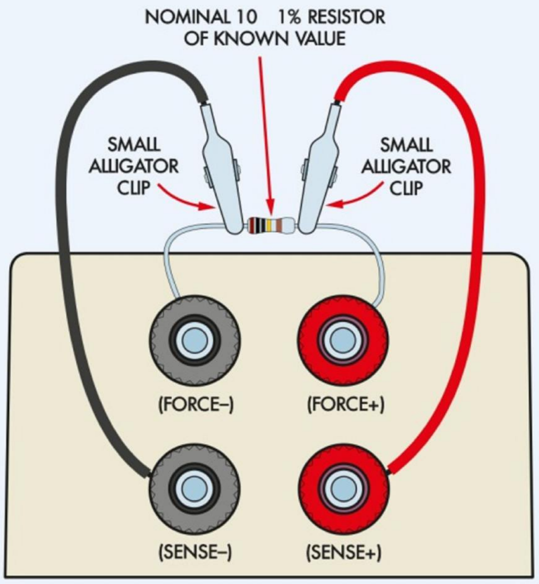


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Fig.8: use this test jig to set up your *Milliohm Adaptor*, as described in the text below

securing it in place with either a small aluminium clamp bracket or a short length of duct tape.

That done, the snap lead can be reconnected to the battery (after first making sure that power switch S3 is in the 'off' position) and finally, the lid/base can be attached to the main part of the box using the four self-tapping screws provided.

Final setup

Your *Milliohm Adaptor* is now complete and ready for its final set-up adjustments. To prepare for these, connect your DMM's test leads to the *Adaptor's* output jacks, using whatever lead(s) will ultimately be used to connect the two and with the correct polarity.

Then switch on power to the DMM and switch it to a low DC voltage range – whichever range allows you to read voltage up to a bit over 1.000V with the best possible resolution. This will be the same range you'll be using when the *Milliohm Adaptor* is ultimately being used with the DMM.

Before switching on, first connect BOTH of the Adaptor's S+ and S– binding posts to the F– binding post, using short lengths of tinned copper wire. Next, make sure that switch S1 is in the EXT sensing position (toggle to the right) and also that there is NO connection to the F+ binding post because it must be left unconnected for this next adjustment.

When you switch on power to the *Milliohm Adaptor* using S3, you'll very likely get a very small but significant reading on the DMM – a few millivolts, in all probability.

The idea is to reduce this reading to zero (or as close as you can get) using a small screwdriver to adjust trimpot VR5 via its matching adjustment hole in the top of the box (at lower centre). You'll find that if you adjust VR5 one way the DMM reading will increase, while if you adjust it the other way it will decrease. So setting the correct zero position is quite easy.

After that, there's only one further set-up adjustment to make: the correct setting for gain trimpot VR4, so that the *Milliohm Adaptor* and DMM combination will give accurate low resistance readings.

To prepare for this final adjustment, first switch off the power using S3 and then remove the wires that were previously used to connect the S+ and S– binding posts to the F– binding post for the zero adjustment.

Now take a 1% tolerance (or better) metal-film resistor with a known value of close to 10.00Ω (measured with your own DMM, perhaps, or ideally with another DMM of higher accuracy) and connect the ends of its leads to the upper binding posts of the *Milliohm Adaptor* (F+ and F–). That done, use a pair of short clip leads to connect the innermost point of each of the resistor's leads to the corresponding sensing binding post, as shown above in Fig.8.

Now make sure that switch S1 is in the EXT sensing position and also that range switch S2 is in the 0-10.0Ω position (toggle to the right). Then apply power via switch S3.

You should see a reading of around 1.000V on the DMM, corresponding to the resistor's value converted using the factor 1mV/10mΩ.

All that, you now need to do is adjust trimpot VR4 using a small screwdriver until the DMM reading corresponds to the known value of your nominal 10Ω resistor. Your *Milliohm Adaptor* will then be set up, calibrated and ready for use.

Using it

Putting the unit to use is quite easy. It's simply connected to the DMM as it was for the final set-up adjustments and with the DMM set to the same low-voltage DC range (to give the best measurement resolution). You then simply connect the low-value resistor to be measured to all four binding posts, as for the final setting-up adjustment.

You can either connect the resistor as shown in Fig.8, or use four separate clip leads if the resistor can't be brought up to the force current binding posts.

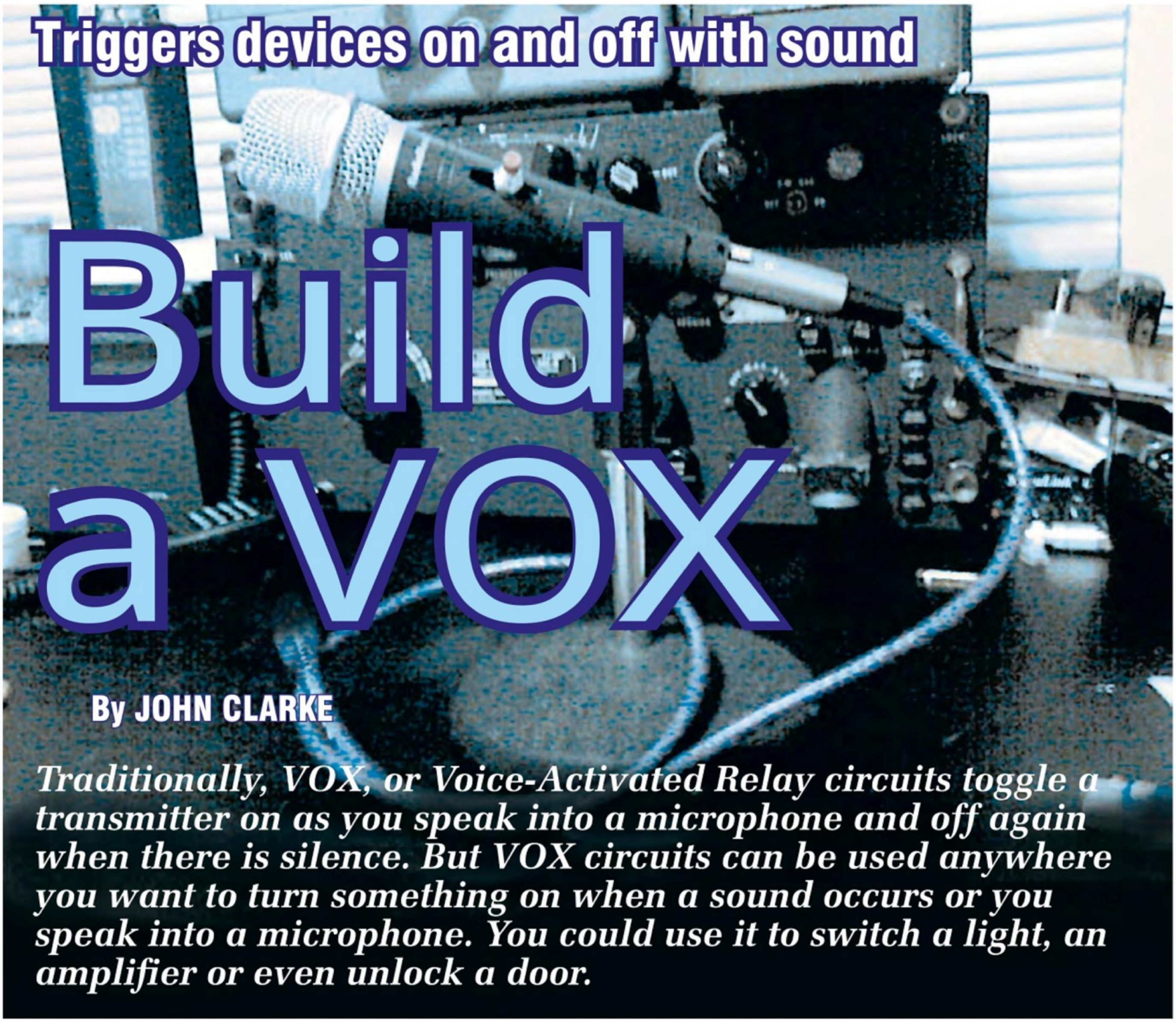
To make the measurement, you need to make sure that S1 is in the EXT sensing position and that S2 is set for the appropriate measurement range (ie, either 0-1.000Ω or 0-10.00Ω, depending on the resistor's value).

When the unit is switched on, the DMM reading will show the unknown resistor's measured value – in millivolts and with a scaling factor of either 1mV/1mΩ or 1mV/10mΩ, depending on the range you're using. So, using the *Milliohm Adaptor* to make four-terminal measurements of low value resistors is really quite easy.

As mentioned earlier though, it can also be used to make 'quick and dirty' (ie, less accurate) two-terminal measurements, if you're in a hurry and accuracy isn't all that important.

To make two-terminal measurements, all you need to do is switch S1 to the INT sensing position and connect the resistor to be measured to only the F+ and F– binding posts – ideally with the shortest practical lead lengths.

Then when you turn on the *Milliohm Adaptor*, the DMM will give you a 'pretty close' reading of the unknown resistor's value. ***EPE***



Triggers devices on and off with sound

Build a VOX

By JOHN CLARKE

Traditionally, VOX, or Voice-Activated Relay circuits toggle a transmitter on as you speak into a microphone and off again when there is silence. But VOX circuits can be used anywhere you want to turn something on when a sound occurs or you speak into a microphone. You could use it to switch a light, an amplifier or even unlock a door.

VOX stands for Voice-Operated eXchange, and it is also the Latin word for 'Voice'. A VOX circuit switches on a relay whenever a signal reaches a set threshold. The relay switches off once the signal level drops below the threshold and after a short delay.

They are used in communications, public address systems, surveillance, security and also general purpose electronics.

For communications, a VOX switches a transceiver from receive to transmit whenever the person speaks into the microphone. This frees the operator for other tasks, because a separate switch is not needed to talk. Many intercoms and public address systems are also automated in a similar way.

A VOX circuit can be used to mute any sound until it reaches a set level. That way, a public address system will ignore background noise and remain quiet, until someone intentionally speaks into a microphone. For security and surveillance, a recorder can be switched on whenever a noise is sensed by a microphone.

But it doesn't have to be a microphone which causes the VOX action. For general-purpose use, any audio signal can be used to switch the relay.

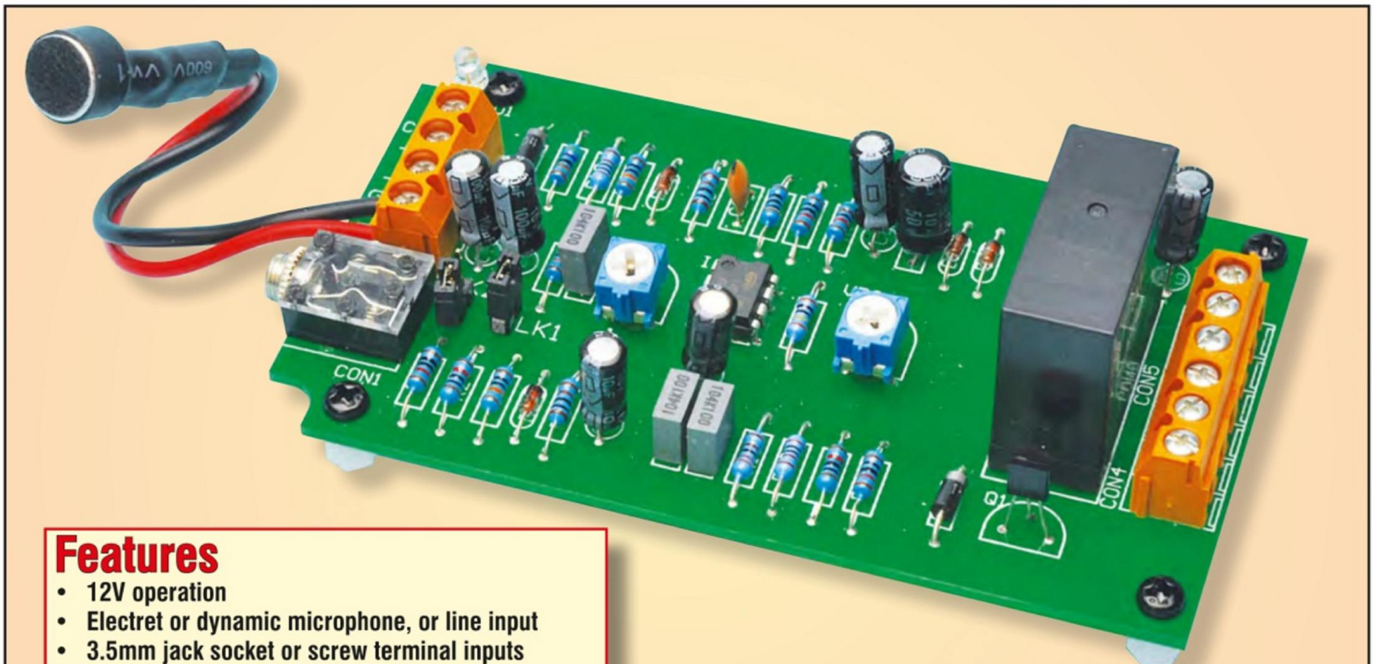
Our design

In line with the above comments, our VOX design has two inputs, both of which will accept the same types of audio input. First is a stereo 3.5mm jack socket, which will handle both mono and stereo signals, while the second input is for mono inputs only and is via screw terminals.

You can connect an electret or dynamic microphone. Electret microphones require a bias voltage, which can be selected with a jumper link (LK1). For stereo signals connected via the 3.5mm socket, a jumper link provides mixing of the left and right channels into a mono signal.

Signal sensitivity can be adjusted to cover a wide range from microphone levels up to line levels of 2V RMS. With sufficient signal, the relay switches on and remains on until the signal level drops to below a threshold level. An adjustable delay sets the time taken for the relay to switch off once this threshold is reached.

The relay has two sets of changeover contacts which will suit a variety of



Features

- 12V operation
- Electret or dynamic microphone, or line input
- 3.5mm jack socket or screw terminal inputs
- Mono or stereo signal
- Adjustable sensitivity
- Adjustable delay
- Hysteresis prevents relay chattering at threshold
- DPDT relay
- Power and relay LED indication

This VOX is quite a versatile beast! It can be used in practically any application which requires triggering from a sound source – and that sound source can be just about anything, including you!

switching applications. LEDs are included for visual indication of power and relay switching.

Because of the wide variety of possible uses for a VOX, our module is simply presented as a PCB which you can install to suit your application. Or if you wish, it can be fitted into a plastic 'UB3' case measuring 130mm × 68mm × 44mm.

Circuit details

The VOX comprises a dual op amp (IC1) that functions as a signal amplifier and threshold switch. The relay is driven from the second op amp via a transistor.

Input signals come in via the 3.5mm jack socket (CON1) or via a 2-way screw terminal block (CON2). For the screw terminal input, one terminal is connected to ground while the other is applied to the amplifier stage via a 10kΩ resistor.

When an electret microphone is used, bias current is selected when link LK1 is closed. The 10kΩ bias resistor is connected to a supply that is decoupled from the 11.4V supply via a 1kΩ resistor and a 100µF capacitor. This decoupling prevents supply variations entering the input to the amplifier to cause false triggering.

If the electret microphone is connected via the stereo jack socket input, the electret is connected between the ground terminal (sleeve) and the tip of a mono jack plug. Again, link LK1 is inserted for electret power.

If an electret is not used and the signal is applied via the jack socket or screw terminals, the link (LK1) is left disconnected. Stereo signals can be connected via the stereo jack socket and the signal is mixed down to mono using 10kΩ resistors for each channel. This stereo mixing occurs when link LK2 is inserted.

Dynamic microphones do not require bias current; in fact, they should not be connected to a circuit providing electret bias, hence the reason for LK1.

A 100nF capacitor couples the mono signal to op amp IC1a. Its non-inverting input, pin 3, is biased from the decoupled supply via two 100kΩ resistors. This sets the amplifier output to swing symmetrically about a nominal half-supply voltage. The half supply will vary from about 5.3V to about 5.6V, depending on whether or not an electret microphone is connected.

Diodes D1 and D2 are included to clamp any signal to +0.6V above the decoupled supply and –0.6V (ie, below the 0V rail). They protect the IC1 input if an excessive signal is applied.

IC1a is connected as a non-inverting amplifier with a gain of 2 when VR1 is set to zero ohms, and a gain of about 1000 when VR1 is set to

Specifications

Power supply:	12VDC at 50mA
Trigger sensitivity:	Adjustable from 2mV (microphone) to 2V (line)
Maximum signal input:	50V rms
Signal frequency range:	16Hz to >600Hz
Attack time:	10 cycles with signal at threshold voltage (faster attack if signal is above threshold)
Hysteresis:	0.44V at the 2.06V threshold
Delay time:	Adjustable from 100ms to 10s
Electret bias current:	~320µA
Relay contacts (DPDT):	5A (maximum of 50V recommended)

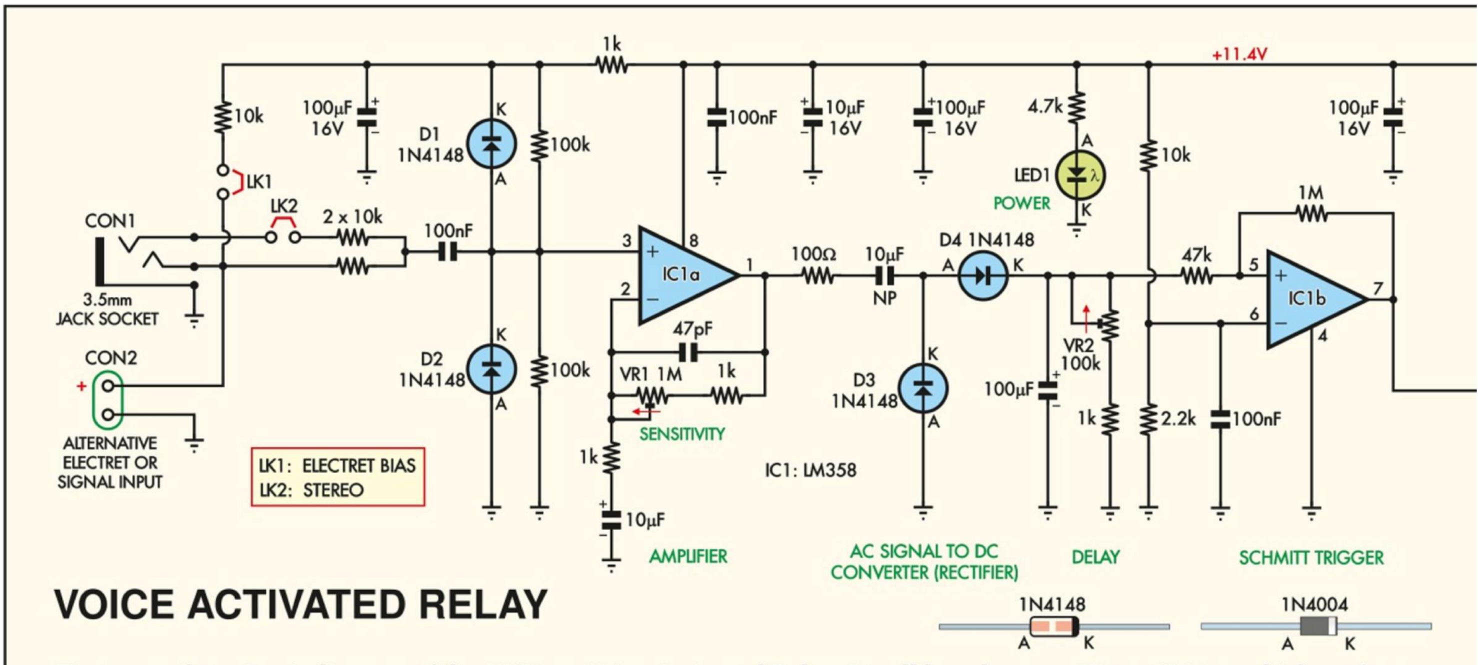
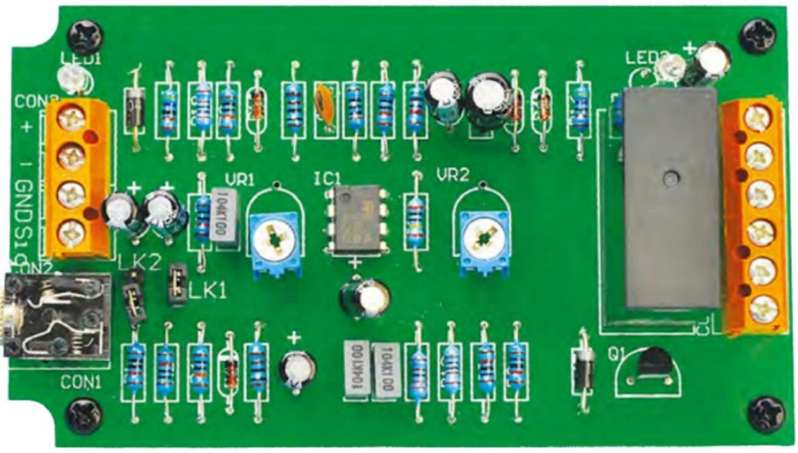


Fig.1: complete circuit diagram of the *VOX*, or *Voice Activated Relay*. It's all based on one IC, an LM358, which performs the dual function of signal amplifier and comparator/schmitt trigger. A handful of other components completes the circuit.



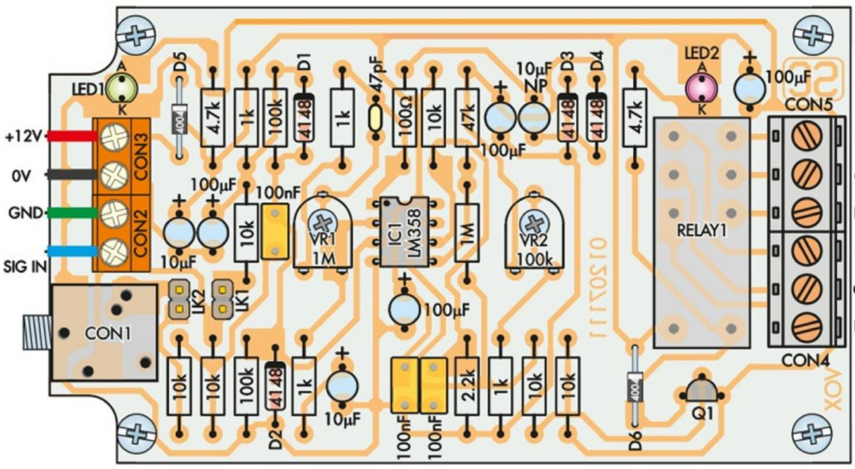


Fig.2: everything mounts on one PCB, shown here in both diagram and photo form. The only thing 'missing' from the PCB is the microphone which must be mounted off the board, otherwise it will 'hear' the relay pulling in and releasing, and more than likely trigger in error. It can be mounted on a short pair of wires if you wish, or as far away as necessary using a shielded microphone cable.

its maximum. The actual gain when VR1 is set to a high value is dependent upon the signal frequency and the open-loop gain of the LM358 op amp.

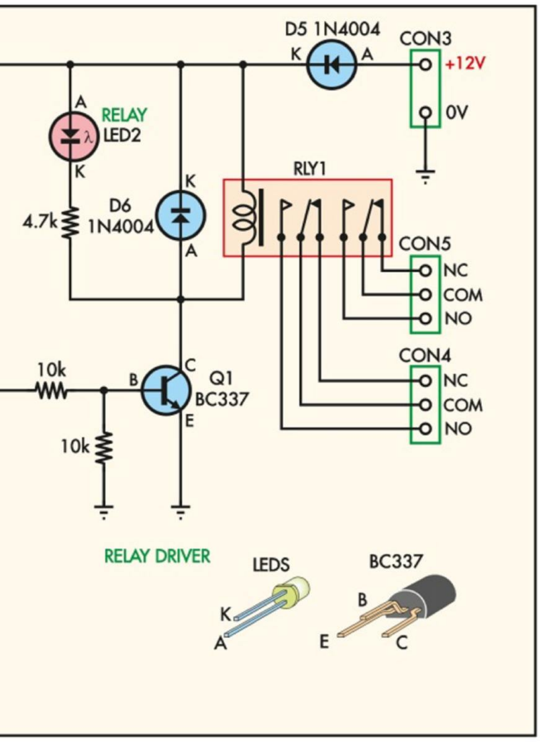
The 47pF capacitor is included to provide a steep roll-off at high frequencies, to ensure IC1 does not oscillate. However, it is the open-loop gain of the amplifier that sets the bandwidth. For example, at a gain setting of 100 (when VR1 is 99kΩ), the roll-off caused by the 47pF capacitor is about 34kHz.

Roll-off due to the open-loop gain is at around 6kHz. With VR1 set for a gain of 1000, the 47pF rolls off frequencies above about 3.4kHz. But the open-loop gain begins to roll off beyond about 600Hz.

Low frequency roll-off is set at about 16Hz. This is due to the 1kΩ resistor and 10µF capacitor connected in series with the inverting input.

The output signal from op amp IC1a is fed to a rectifier involving diodes D3 and D4, to convert the AC signal to a DC voltage. As pin 1 swings above its resting position of 5.7V, the 10µF capacitor discharges via diode D4 into the 100µF capacitor at D4's cathode. When pin 1 swings below 5.7V, the 10µF capacitor discharges via D3. The 100µF capacitor then charges with repetitive pulses provided by the 10µF capacitor.

Op amp IC1b is connected as a Schmitt trigger comparator, with the inverting input at pin 6 tied to a voltage divider comprising a 10kΩ and 2.2kΩ



Parts List – VOX

1 PCB, code 01207111, available from the *EPE PCB Service*, size, 106mm × 61mm
1 DPDT 12V relay, 5A contacts (RLY1)
1 3.5mm PCB-mount stereo socket (CON1)
2 2-way PCB-mount screw terminals with 5.08mm pin spacing (CON2,CON3)
2 3-way PCB-mount screw terminals with 5.08mm pin spacing (CON4,CON5)
1 electret microphone insert (MIC1) (if required – see text)
11MΩ horizontal mount trimpot (code 105) (VR1)
1100kΩ horizontal mount trimpot (code 104) (VR2)
2 2-way pin headers with 2.54mm pin spacing (LK1,LK2)
2 2.54mm jumper shunts
4 M3 tapped spacers (optional)
4 M3 × 6mm screws (optional)
1 length of hookup wire or single cored shielded cable

Semiconductors
1 LM358N dual op amp (IC1)
1 BC337 *NPN* transistor (Q1)
4 1N4148 switching diode (D1-D4)
2 1N4004 1A diodes (D5,D6)
2 3mm red LEDs, 1 red and 1 green (LED1,LED2)

Capacitors
3 100μF 16V electrolytic
1 10μF Non Polarised (NP) electrolytic
2 10μF 16V electrolytic
3 100nF MKT polyester
1 47pF ceramic

Resistors (0.25W 1%)

1 1MΩ	2 100kΩ
1 47kΩ	6 10kΩ
2 4.7kΩ	1 2.2kΩ
4 1kΩ	1 100Ω

resistor across the 11.4V supply. Pin 6 sits at about 2.06V and is bypassed with a 100nF capacitor.

IC1b's non-inverting input, pin 5, monitors the voltage across the 100μF capacitor via a 47kΩ resistor. When the 100μF capacitor voltage is below pin 6, IC1b's output at pin 7 is low; close to 0V. When the capacitor voltage rises above pin 6, pin 7 will go high to about +10V. So, provided the AC signal fed to the rectifier is enough to produce more than 2V across the 100μF capacitor, pin 7 of IC1b will go high and this will turn on transistor Q1 and the associated relay.

Now, one of the problems with a trigger circuit like IC1b is that it will not switch cleanly from high to low, since a very slight change in the voltage across the 100μF capacitor could mean that it switches back and forth very rapidly. This would result in the relay chattering, ie, switching on and off very rapidly.

We fix this by adding hysteresis to the circuit, by including the 1MΩ resistor between pin 5 and 7. What now happens is that when the output switches high, it also pulls pin 5 slightly higher, 0.35V higher than the 100μF capacitor voltage. This means that the capacitor has to discharge by this amount before IC1b will go low again. This stops the relay chatter.

The 100μF capacitor is continually discharged via VR2 and the 1kΩ resistor. So if the signal from IC1a is not continuously replenishing the 100μF capacitor, the voltage will drop in level. VR2 sets the delay period from when IC1b is triggered high to when its output goes low in the absence of signal from IC1a.

The VOX runs from a 12V supply; diode D5 is included for reverse polarity protection. LED1 indicates when power is present.

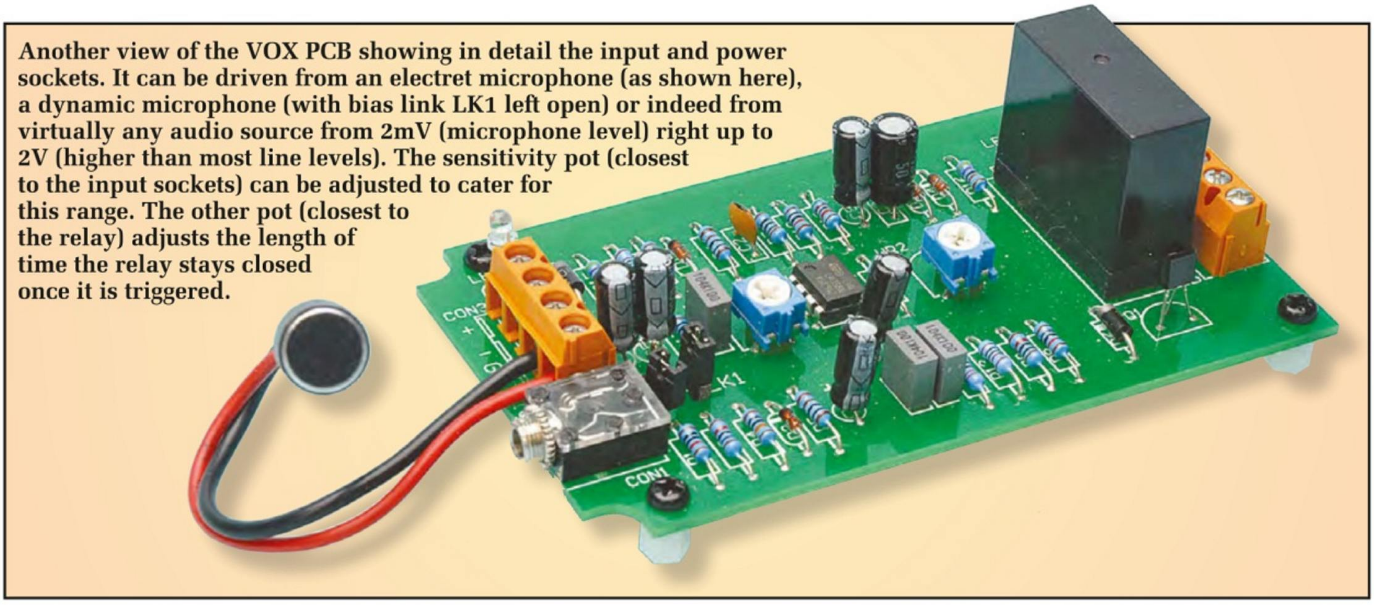
Construction

The VOX is assembled on a PCB, code 01207111 and measuring 106mm × 61mm. This PCB is available from the *EPE PCB Service*. All of the components are mounted on the PCB, apart from the microphone, which must not be – it needs to be off the board so that it does not attempt to retrigger the circuit whenever it 'hears' the relay switch off.

The PCB is sized to clip into the integral side slots of a UB3 utility box measuring 130mm × 68mm × 44mm. If you are using this box, make sure the left edge of the PCB is shaped to the correct outline so it fits into the box, clearing the internal corner pillars. That way, the 3.5mm socket can pass through the end of the box. It can be filed to shape if necessary, using the PCB outline shape as a guide.

Begin construction by checking the PCB for breaks in tracks or shorts between tracks or pads. Repair if necessary. Check hole sizes for the components and for the corner mounting holes.

Assembly can begin by inserting the resistors. When doing this, use a digi-



Another view of the VOX PCB showing in detail the input and power sockets. It can be driven from an electret microphone (as shown here), a dynamic microphone (with bias link LK1 left open) or indeed from virtually any audio source from 2mV (microphone level) right up to 2V (higher than most line levels). The sensitivity pot (closest to the input sockets) can be adjusted to cater for this range. The other pot (closest to the relay) adjusts the length of time the relay stays closed once it is triggered.

tal multimeter to measure each value. Next come the diodes, remembering these must be mounted with the orientation shown. There are two types of diodes; D1 to D4 are the smaller 1N4148 types, while D5 and D6 are the larger 1N4004 devices.

IC1 can be soldered directly into the PCB (or you can use a DIP8 socket if you wish). When installing the IC (and socket), take care to orient them correctly. Orientation is with the notch positioned as shown.

Capacitors can be mounted next. The electrolytics must be oriented with the shown polarity except for the *NP* (non-polarised) type that can mount either way.

Mount the transistors and trimpots VR1 and VR2. VR1 is the 1MΩ trimpot and could be marked with its value or with the coding 105. VR2, the 100kΩ pot could be marked as 104.

LED1 and LED2 are mounted about 5mm above the PCB. The anode is the longer lead and is placed in the uppermost hole.

The 2-way pin headers for LK1 and LK2 can be mounted now, followed by the 3.5mm socket, the relay and the screw terminals. CON1 and CON2 are 2-way terminals that are first attached by sliding the dovetail sections of each together. Similarly for the CON3 and CON4 terminals, these are slid together before being mounted on the PCB. Make sure the wire entry side faces the outside of the PCB.

We mounted the PCB on four 6mm-long tapped spacers, held in place with M3 × 6mm screws, but this is entirely up to you and your application.

If your project is using an electret microphone, this should be mounted so that it does not touch the PCB and is connected via multi-strand hookup wire for short (less than 30mm) leads. Use single-core shielded cable for longer runs. The shield wire connects to the GND terminal (for the 3.5mm jack plug, the GND is the sleeve). Signal connects to the second screw terminal for the screw terminal input or the tip connection of the 3.5mm jack plug.

For a signal input other than a microphone, apply the signal to either the screw terminals or via a 3.5mm jack plug. One channel connects to the tip terminal and the other channel to the ring terminal.

Link selection depends on whether you are using an electret or dynamic microphone, or a mono or stereo signal connection. LK1 should be linked only when the electret microphone is used, and removed for a dynamic mic.

LK2 should have a jumper link for a stereo signal. You wouldn't normally have both LK1 and LK2 in position at once, but there are stereo electret microphones around, so it is possible you'll use this combination (although why you'd want to use one in this application is a bit beyond us!).

Apply 12V power and adjust VR1 so that the relay triggers at the required signal level. Similarly, adjust VR2 so that the relay switches off after the desired time period. The delay should be as short as possible, but not so short that it drops out while speaking.

If the *Voice-Activated Relay* does not work, first check your soldering to make sure there are no dry joints, solder bridges or dags.

If the visual inspection looks OK, check voltages on the circuit. There should be about 11.4V between pins 4 and 8 of IC1. Pin 3 of IC1 should be around 5.7V to 5.3V. Pin 6 of IC1b should be at about 2V.

Incorrect voltages may be because of incorrect resistor values or a short- or open-circuit connection. Check that LED 1 lights. The output of IC2 at pin 7 should be near 0V when no signal is applied (or when no sound is detected by the microphone).

With sufficient signal applied, the pin 7 output should go to around 10V, the relay should switch on and LED2 should light. The relay should switch off after the preset time period when there is no signal.

Is 9V operation feasible?

We know we will be asked this question! Some constructors may wish to use the VOX as a stand-alone device – so here's the answer!

'No', operation from 9V would be quite unreliable, especially if the battery is a bit flat. And the 50mA current draw would put the battery in that state pretty quickly!

Most of the circuit would be fine at 9V, but the 12V relay would not be at all happy (if indeed it worked at all). Substituting a 5V relay may be an option, with a resistor in series with the coil, but it may not be possible to get one which fits the PCB without modification. ***EPE***